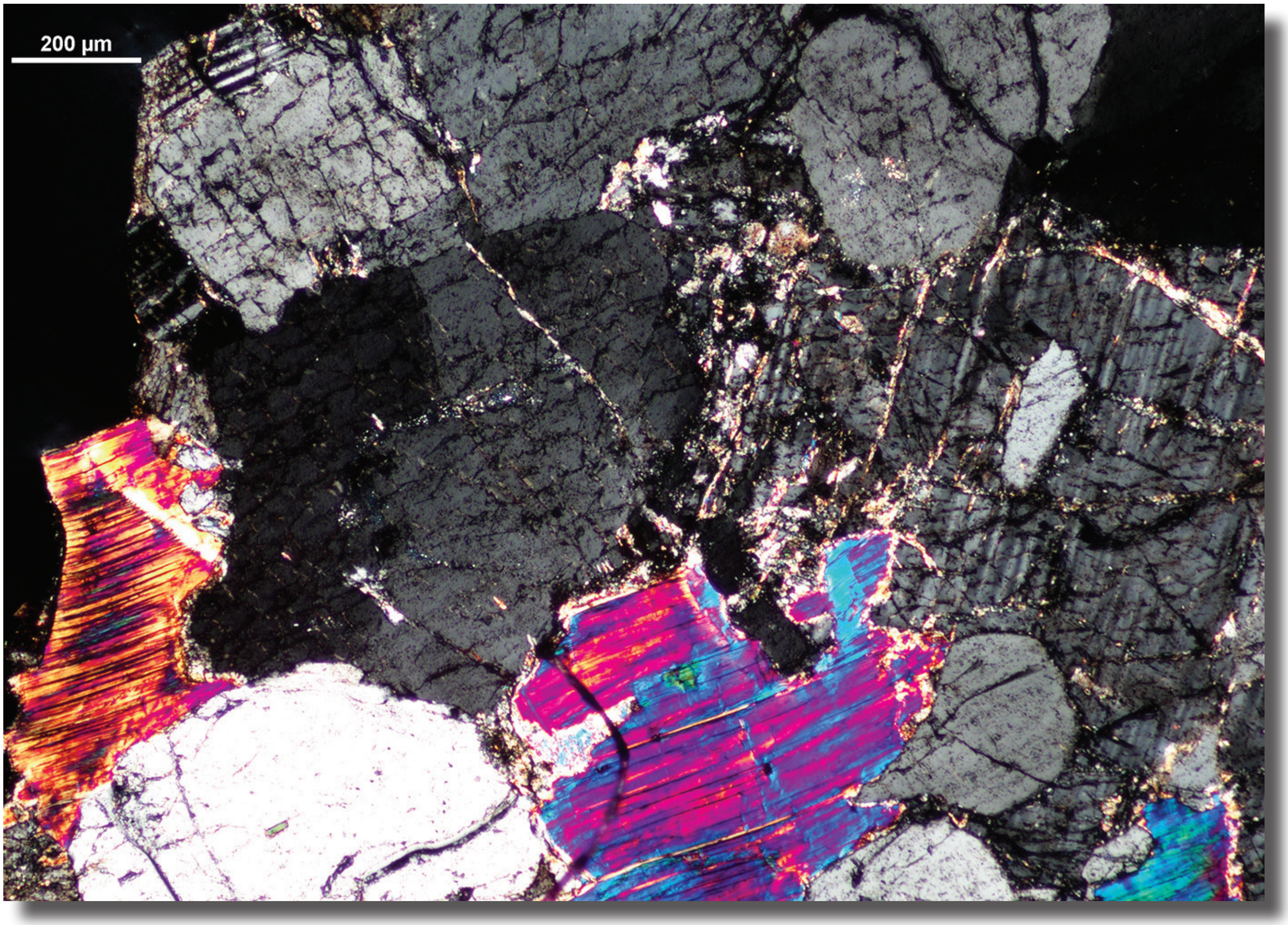
Geologic Map of Pre-Middle Jurassic Basement Rocks Beneath the Atlantic and Gulf Coastal Plains in Florida

By Ryan T. Deasy, J. Wright Horton, Jr., Shannon N. Glock, Mary E. Lupo, E. Allen Crider, Jr., and David L. Daniels



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Cover: Photomicrograph in cross-polarized light of a cuttings fragment of massive, muscovite-bearing granite from borehole W12509 in northwestern Gulf County, Florida, at a depth of 13,080 to 13,090 feet. Cuttings from this and two other boreholes represent what was recovered of the informal Gaskin intrusive complex (Winston, 1992), which subcrops under the Florida panhandle. Argon-argon ($^{40}Ar/^{39}Ar$) analyses of potassium feldspar and muscovite and uranium-lead analysis of zircon from this granite establish a crystallization and cooling history for the Gaskin intrusive complex that is approximately 100 million years older than for other Neoproterozoic granitoids in Florida. Abbreviation: µm, micrometer. Photomicrograph by Ryan T. Deasy, U.S. Geological Survey.

Acknowledgments

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
micrometer (µm)	0.00003937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	25,400	micrometer (µm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datums

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Abbreviations

°C	degree Celsius
>	greater than
<	less than
BMA	Brunswick magnetic anomaly
Ga	giga-annum (billion years before present)
HFSE	high field strength element
HREE	heavy rare earth element
HZ	Higgins-Zietz line
IDW	inverse distance weighting
IUGS	International Union of Geological Sciences
LREE	light rare earth element
m.y.	million years
Ma	mega-annum (million years before present)
Mg#	magnesium number (molar ratio of magnesium oxide and combined iron and magnesium oxides, expressed as a percent)
MORB	mid-ocean ridge basalt
$_N$	chondrite-normalized
n	number (of samples)
REE	rare earth element
sec	second (unit of time)
SHRIMP	sensitive high-resolution ion microprobe
USGS	U.S. Geological Survey

Symbols for Elements and Compounds

Al	aluminum
Ar	argon
Ca	calcium
Ce	cerium
CO_2	carbon dioxide
Dy	dysprosium
Er	erbium
Eu	europium
Fe	iron
Gd	gadolinium
Ho	holmium
K	potassium
La	lanthanum
Lu	lutetium
Mg	magnesium
Na	sodium
Nb	niobium
Nd	neodymium
O	oxygen
Pb	lead
Pr	praseodymium
Rb	rubidium
Sm	samarium
Sr	strontium
Tb	terbium
Ti	titanium
Tm	thulium
U	uranium
Y	yttrium
Yb	ytterbium
Zr	zirconium

Geologic Map of Pre-Middle Jurassic Basement Rocks Beneath the Atlantic and Gulf Coastal Plains in Florida

By Ryan T. Deasy,[1] J. Wright Horton, Jr.,[2] Shannon N. Glock,[3] Mary E. Lupo,[4] E. Allen Crider, Jr.,[1] and David L. Daniels[5]

Abstract

Much of the southeastern United States, including all of Florida, is covered by flat-lying sedimentary strata of the Atlantic and Gulf Coastal Plains which have accumulated since Middle Jurassic time. The pre-Middle Jurassic rocks that underlie these coastal plains in Florida, here collectively referred to as “basement,” are known only from a relatively small number of boreholes. This scientific investigations map presents an interpretation of the basement geology in a 1:1,000,000-scale subsurface geologic map with supporting text, data, and figures. The subsurface mapping methodology integrates petrographic, geochronological, thermochronological, geochemical, and mineralogical analyses of drill cores and cuttings in the context of regional geophysical data.

The pre-Middle Jurassic rocks of Florida consist of the Gondwanan (West African) Suwannee terrane which was accreted to Laurentia during the Alleghanian orogeny and subsequently intruded by Permian granites, superposed by early Mesozoic rift basins, and partially overlain by bimodal Jurassic volcanic rocks. The younger basement components, specifically the Southwest Florida volcanic province (J₸sf), North Florida tholeiites (Jt), early Mesozoic rift basins (represented by unit J₸b), and Alleghanian granitoids (represented by units Pfcg and Pg), have correlative and contemporaneous units throughout the Appalachian orogen. In contrast, Florida’s older basement rocks, including Paleozoic siliciclastic strata of the Suwannee basin, North Florida volcanic series (€Znf), Osceola and Gaskin intrusive complexes (€Zo and Zg, respectively), and the St. Lucie Metamorphic Complex (Zsl), have neither surface exposures nor unequivocal correlates. Major structures include early Mesozoic normal faults and northwest-striking transfer zones such as the Jay fault. Many of these faults define the boundaries of subbasins within the South Georgia rift system. Top-of-basement structure contours show gentle arches and embayments that are also recognized in overlying coastal plain strata.

Introduction

Basement terranes and rift basins concealed beneath the Atlantic and Gulf Coastal Plains in the southeastern United States are among the last frontiers of regional geology in the United States. Common use of the term “basement rock” in the Atlantic and Gulf Coastal Plains refers to Paleozoic and older crystalline and sedimentary rocks as well as rift-related Triassic to Early Jurassic sedimentary and igneous rocks that lie beneath the coastal plain sedimentary strata (Chowns and Williams, 1983; Daniels and Leo, 1985; Lloyd, 1985; Wait and Davis, 1986; Arthur, 1988; Guthrie and Raymond, 1992). The top of basement in Florida, that is, the Fall Line unconformity (Chowns and Williams, 1983), which separates basement rocks from the coastal plain sequence, ranges from as shallow as 2,438 feet [ft]) below sea level in northeastern Florida (Horton and others, 2023) to ~15,000 ft in the Florida panhandle and >18,600 ft in southern Florida (fig. 1). No borehole has yet penetrated basement rocks in southernmost Florida; the exact depth and nature of basement rocks there remain unknown.

The pre-Middle Jurassic basement rocks of Florida include accreted Gondwanan crust of the Suwannee and West Florida terranes, parts of the largest Mesozoic rift system in eastern North America (the South Georgia rift system), and smaller rift basins concealed beneath coastal plain sediments (fig. 2). Map units are discriminated by petrographic, mineralogical, and geochemical characteristics as determined by analyses of drill core and cuttings. The subcrop extents of map units are approximate due to the low spatial density of basement penetrations (<1 borehole per 1,000 square kilometers [km^2]) but are significantly constrained by seismic data (fig. 3; Arden, 1974) and newly reprocessed airborne gravity survey data (fig. 4; Dater and others, 1999) and aeromagnetic data (fig. 5; U.S. Naval Oceanographic Office, 1970; U.S. Geological Survey, 1978a, b, c, d; Behrendt and Klitgord, 1979; Hill and others, 2009).

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[4] Florida Geological Survey.

[5] U.S. Geological Survey, retired.

The aeromagnetic data were reprocessed by the following method. First, the residual composite magnetic field was simulated 305 meters (m) above ground and reduced to the pole (inclination = 83°, declination = 3°). Next, the Definitive Geomagnetic Reference Field was removed from each data point according to the date of that survey (Thébault and others, 2015). Before merging, data points for each survey were interpolated into a grid using a minimum-curvature algorithm; grid intervals were selected as appropriate to the flight-line spacing. The five grids were then adjusted to a common drape altitude of 305 m using continuation programs, then joined one survey at a time using a suturing program starting with the most recent survey. The merging routine permits favoring surveys with the more desirable qualities at the join. Lastly, a directional filter was applied to some grids to reduce flight-line striping, the composite grid was colored, and east-sourced shading was applied. All processing was done using Geosoft Oasis montaj software.

The ages of many crystalline rocks are constrained by geochronological and thermochronological data from samples within Florida and neighboring States. The ages of most sedimentary units are constrained by biostratigraphic evidence. However, some units have only relative age constraints. Occurrences of pre-Middle Jurassic basement rocks are identified herein by Florida Geological Survey borehole number. Petrographic observations of basement rock samples are detailed in an accompanying data report (Deasy and others, 2026b). We additionally refer the reader to data releases associated with this scientific investigations map. These include (1) basement borehole data (Horton and others, 2023), (2) whole-rock geochemical data (Deasy and others, 2024a), (3) whole-rock mineral abundances (Deasy and others, 2024b), and (4) photographs and photomicrographs of basement rock samples (Deasy and others, 2024c). A database for the geologic map data is available in another data release associated with this scientific investigations map (Deasy and others, 2026a).

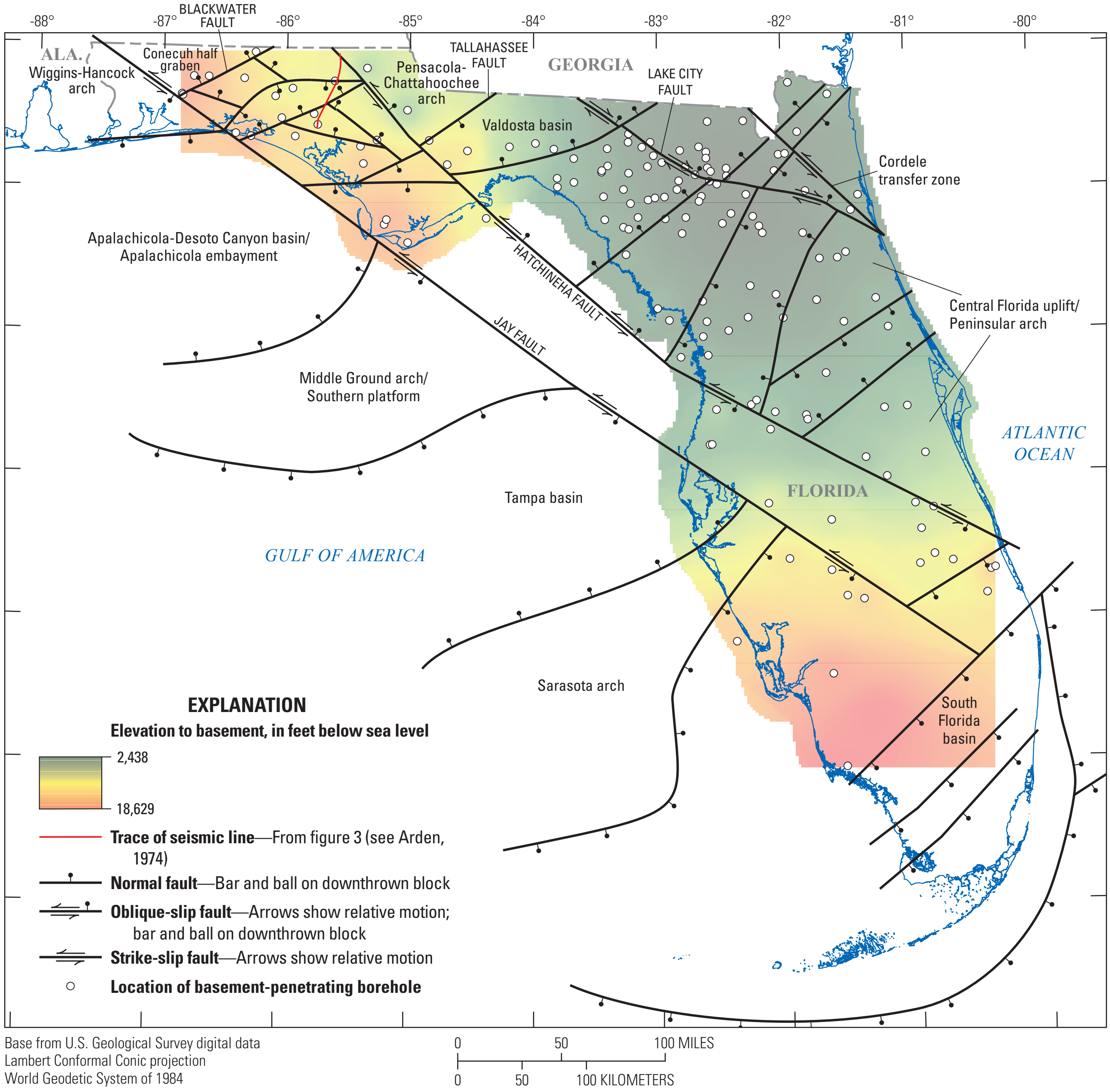
Previous Work and Geologic Setting

Pre-Middle Jurassic basement rocks in Florida are known exclusively from drill core and cuttings. Boreholes that have penetrated basement rocks were drilled between 1928 and 1990 and number 146 in total. Of these boreholes, 22 were drilled into lower Mesozoic siliciclastic or volcanic rock; 85 into Paleozoic sedimentary rocks; 11 into Neoproterozoic to lower Paleozoic volcanic rock; 15 into massive granitic, granodioritic, or dioritic rock; and 3 into metamorphic rock (Horton and others, 2023). Several boreholes encountered multiple rock types. Additionally, 30 boreholes encountered basaltic dikes or sills. The amount of basement rock recovered from each borehole varies from as much as tens of kilograms across hundreds of drilled feet to as little as a few grams of cuttings from a single 10-ft interval.

Early contributions to Florida basement rock studies include petrographic studies and compilations of borehole data in Florida (Applin, 1951; Milton, 1972) and surrounding States (Chowns and Williams, 1983; Guthrie and Raymond, 1992). Geochemical studies (Chowns and Williams, 1983; Mueller and Porch, 1983; Arthur, 1988; Heatherington and Mueller, 1991; Heatherington and others, 1996) provide insight into the petrologic and tectonic history of the igneous rocks. Geochronological studies by the potassium-argon (K-Ar), rubidium-strontium (Rb-Sr), or other whole-rock dating methods identified lower Mesozoic volcanic rocks (Bass, 1969; Milton and Grasty, 1969; Scholle, 1979). Alleghanian plutonism was first indicated in Florida by Late Pennsylvanian to early Permian (Cisuralian) crystallization ages of zircon in massive granite (Heatherington and others, 2010).

Wilson (1966) may have been the first publication to suggest that Florida's older rocks detached from the West African platform (Gondwana) upon the opening of the Atlantic Ocean. The allochthonous crust underlying Florida was variably termed the "Northern Florida magnetic terrane" (Higgins and Zietz, 1983) and "Tallahassee-Suwannee terrane" (Williams and Hatcher, 1983) before consensus settled on the term "Suwannee terrane" (informal name of Horton and others, 1989, 1991). A Gondwanan origin for the Suwannee terrane is supported by paleontological (Pojeta and others, 1976), paleomagnetic (Opdyke and others, 1987), isotopic (Heatherington and Mueller, 1999), and geochronological (Mueller and others, 1994; Heatherington and others, 1996; Mueller and others, 2014) evidence. Specific correlation of the Suwannee basin (informal name of King, 1961) with the Bové basin in present-day Sierra Leone is suggested by paleontological data (Cramer, 1973). Stratigraphic evidence (Duncan, 1998) is also permissive of this correlation. Thermochronological evidence (Dallmeyer, 1987, 1989b, c; Dallmeyer and others, 1987) supports the correlation of the Osceola arc (informal name of Boote and others, 2018) and St. Lucie Metamorphic Complex with the Rokelide orogen (also in present-day Sierra Leone) and further supports a West African origin for the Suwannee terrane. However, isotopic data from Mesozoic tholeiitic basalts that have intruded through the Suwannee terrane have been interpreted to support the correlation of the Suwannee and Carolina terranes with South American parts of Gondwana (Heatherington and Mueller, 1999, 2003). Moreover, recent work (Deasy and McAleer, 2022; Deasy and others, 2023) has shown that the Gaskin intrusive complex (informal name of Boote and others, 2018) is approximately 100 million years (m.y.) older than the Osceola arc. Further research could help to resolve correlations among these tectonic components.

Geophysical investigations have always been critical to understanding basement rock structure in Florida (refer to Barnett, 1975, and references therein). Taylor and others (1968) provided an aeromagnetic map of the Atlantic margin from Maine to Florida and inferred several structures in and age relationships among the basement rocks. Arden (1974) contributed an interpretation of the basement structure of northwestern Florida from seismic data. More recent seismic studies have placed limits on the subcrop extents of early Mesozoic basins in northern Florida (Heffner, 2013) and delineated terrane boundaries outside the State (Boote and Knapp, 2016; Ehrlich and Pindell, 2021). Still, debate persists as to whether the northern extent of the Suwannee terrane is coincident with the Higgins-Zietz line (Boote and others, 2018) or the Brunswick magnetic anomaly (fig. 2; Mueller and others, 2014). More details of previous contributions to Florida basement rock studies are included in the discussion below and in the companion data report (Deasy and others, 2026b).



Base from U.S. Geological Survey digital data
Lambert Conformal Conic projection
World Geodetic System of 1984

Figure 1. Map showing elevation below sea level of the top of pre-Middle Jurassic basement rocks in Florida and locations of inferred faults and other structural features. The raster image was generated from borehole depths to basement using the inverse distance weighting (IDW) raster interpolation tool in the ArcMap 10 3D Analyst Tools toolbox. Refer to the map sheet for borehole numbers. Structures south of the Jay fault are based on data in figure 1 of Ehrlich and Pindell (2021).

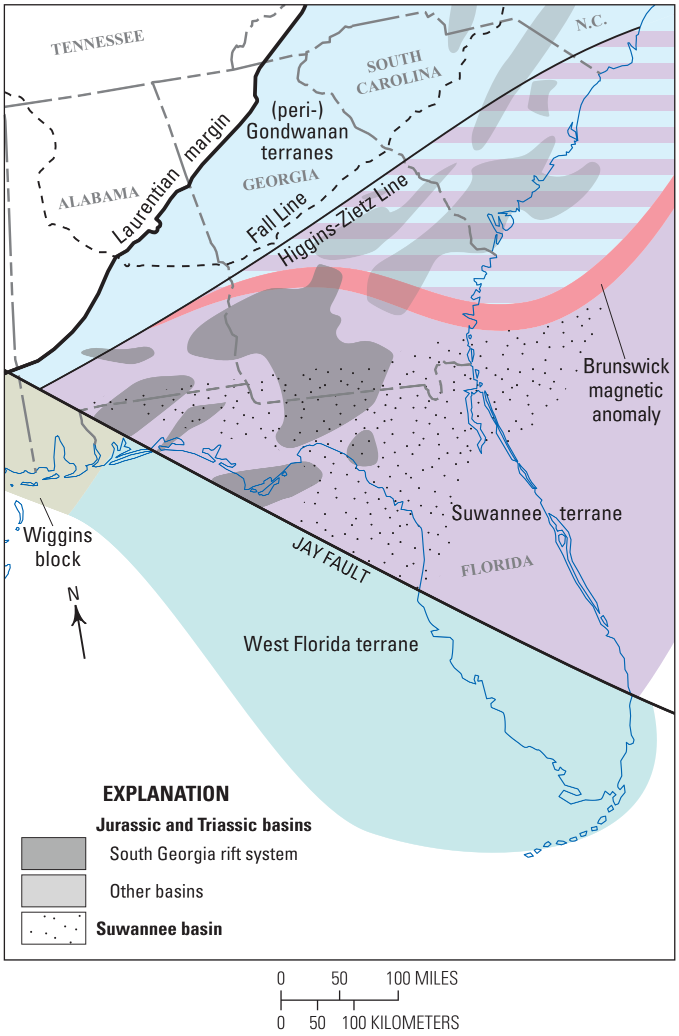


Figure 2. Generalized map of Florida and adjacent States showing terranes and other features. Locations of buried early Mesozoic rift basins are from Heffner (2013). Most of Florida is underlain by the Gondwanan Suwannee terrane, which is juxtaposed against the West Florida terrane (Ehrlich and Pindell, 2021) and the Wiggins block across the Jay fault. The northern extent of the Suwannee terrane has been interpreted to be near or coincident with either the Brunswick magnetic anomaly (BMA) (Mueller and others, 2014, fig. 2) or the Higgins-Zietz line (HZ), a major lineament in aeromagnetic surveys (Higgins and Zietz, 1983; Boote and others, 2018). Locations of the Fall Line and Laurentian margin are from Mueller and others (2014).

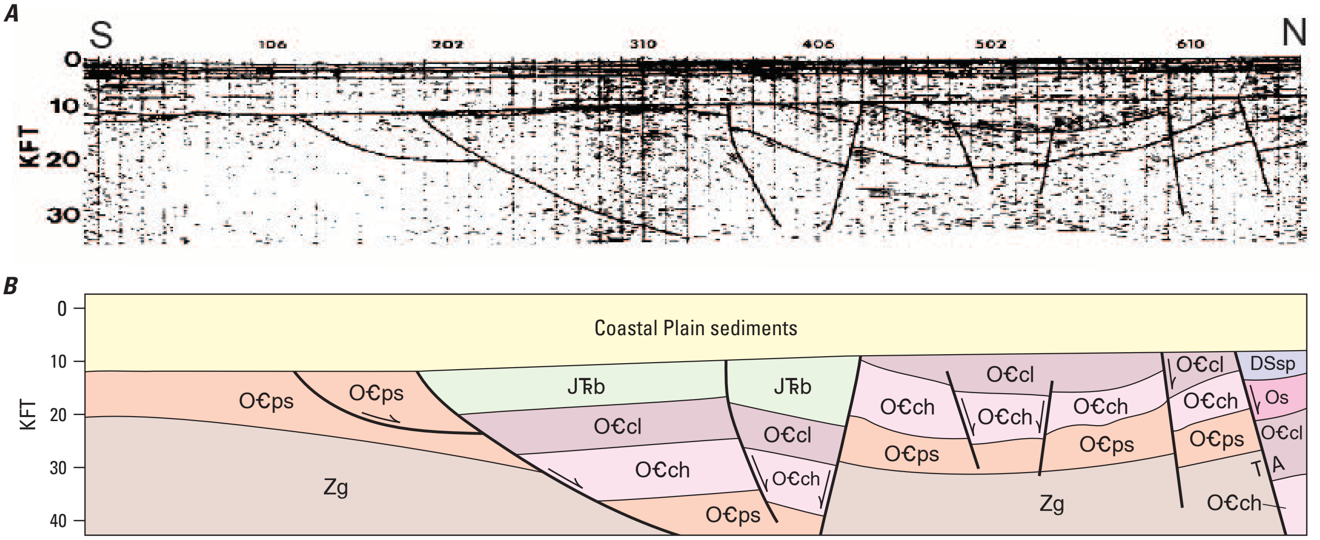


Figure 3. Basement geology of northwestern Florida as shown in (*A*) a migrated-depth seismic section from Arden (1974) and (*B*) a new interpretation of units in part *A*. The seismic section runs through part of the South Georgia rift system. The trace of the section is shown in figure 1 and also on the geologic map. Part *A* is copyrighted by the Gulf Coast Association of Geological Societies (1974); used with permission. Abbreviations: A, motion away from observer; KFT, thousands of feet below sea level; T, motion toward observer.

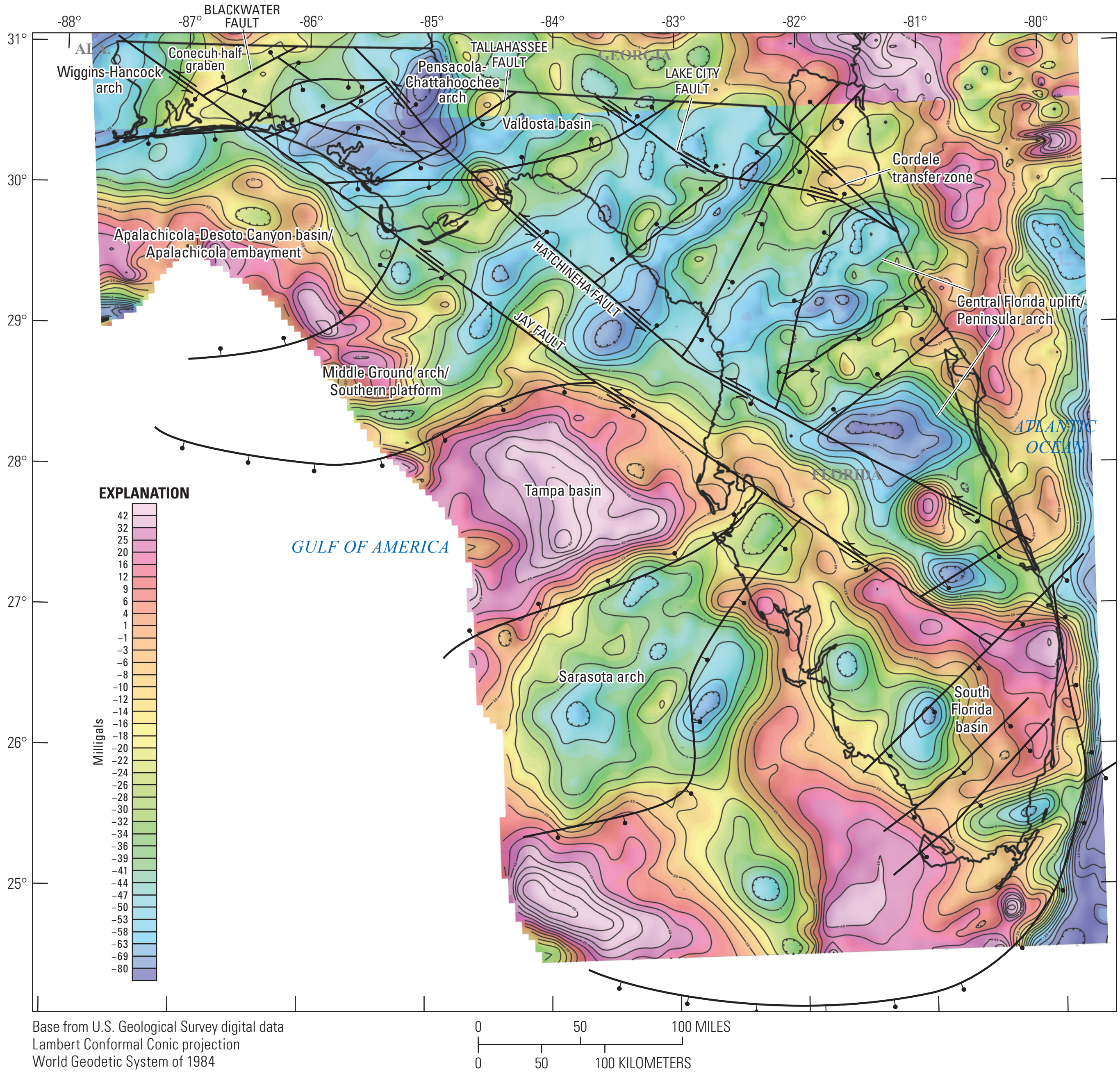
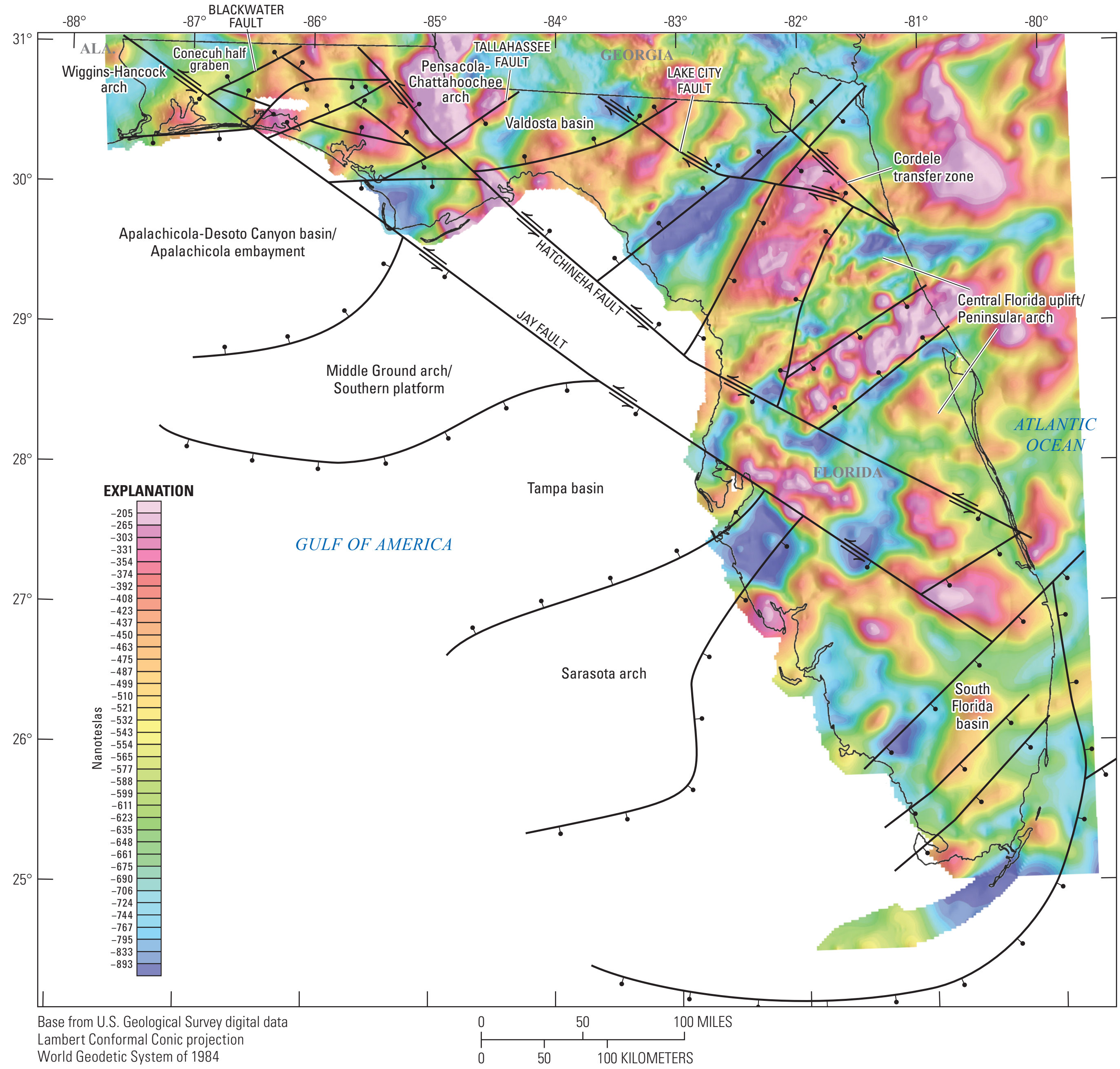


Figure 4. Gravity anomaly map of Florida and surrounding areas showing simple Bouguer anomaly on land and free-air anomaly over water, with locations of inferred faults and other structural features. Vertical scale on the side represents gravitational acceleration in milligals (mGal), shown in color (red = high; blue = low). Gravity contours marked with hachures represent closed depressions. Compiled and processed by David L. Daniels (U.S. Geological Survey). Gravity anomaly data were obtained from National Geophysical Data Center databases (Dater and others, 1999).



Base from U.S. Geological Survey digital data
Lambert Conformal Conic projection
World Geodetic System of 1984

Figure 5. Aeromagnetic map of Florida and surrounding areas showing the locations of inferred faults and other structural features. Vertical scale on the side represents total magnetic field strength in nanoteslas (nT), shown in color (red = high; blue = low). The aeromagnetic map is a composite of five separate surveys flown using different parameters between 1966 and 1981. Compiled and processed by David L. Daniels (U.S. Geological Survey). Aeromagnetic data were obtained from U.S. Naval Oceanographic Office (1970), U.S. Geological Survey (1978a, b, c, d), Behrendt and Klitgord (1979), and Hill and others (2009).

Suwannee Terrane

The Neoproterozoic and Paleozoic rocks of the Suwannee terrane include the Gaskin intrusive complex (Zg); the St. Lucie Metamorphic Complex (Zsl); the Osceola arc, which comprises the Osceola intrusive complex (€Zo; informal name of Boote and others, 2018) and the North Florida volcanic series (€Znf; informal name of Heatherington and others, 1996); and sedimentary rocks of the Suwannee basin.

Gaskin Intrusive Complex

The name "Gaskin granite" was first applied to the granite in borehole W12509 by Winston (1992). The term was later broadened to Gaskin intrusive complex (Zg) to include a granodiorite in borehole W12497 and other granitoids in the area. A region of anomalously low gravity enclosing these boreholes (fig. 4) is interpreted as the extent of the Gaskin intrusive complex (Zg) in northwestern Florida.

Zircons from the granite in borehole W12509 have Neoproterozoic ages (656±38 Ma [mega-annum, million years before present]; n=6; Deasy and others, 2023). Euhedral muscovite flakes from the same sample (cover photograph; Deasy and others, 2026b, figs. 19 and 21) yielded an argon-argon ($^{40}Ar/^{39}Ar$) plateau age of 653.8±3.4 Ma (Deasy and McAleer, 2022). This is interpreted as very rapid cooling from crystallization at the minimum depths and temperatures necessary to stabilize magmatic muscovite (~12–15 km and ~650 degrees Celsius [°C]). Zircons from drill cuttings of granodiorite from southern Alabama have been dated to 625±2 Ma (Heatherington and Mueller, 1994). Neoproterozoic ages are tentatively presumed for the other granite (W12309) and granodiorite (W12497) that represent this unit in Florida.

Although the rocks representing this unit all have metaluminous compositions (fig. 6), samples from each of the three boreholes are otherwise petrographically, geochemically, and mineralogically distinct (Deasy and others, 2024a, b). The Gaskin "type" granite of borehole W12509 contains magmatic muscovite and no mafic silicate minerals. Magnetite is common and commonly intergrown with apatite; the abundance of these two minerals increases significantly with depth. Abundances of rare earth elements (REEs) in this rock increase with depth across a ~30-ft sample interval (n=5), a trend which correlates with the abundances of apatite and magnetite (fig. 7; Deasy and others, 2026b, figs. 28–32). This is interpreted as resulting from internal fractionation and differentiation. All samples of this rock have moderate europium (Eu) anomalies ($Eu/Eu^* = Eu / (Sm \times Gd)^{1/2} = 0.49–0.60$, n=5; fig. 7*A*) indicating fractionation and loss of plagioclase during its crystallization history. (The term "Eu/Eu*" is a standard notation for the europium anomaly, which is calculated by dividing measured Eu concentrations by the geometric mean of the measured concentrations of samarium [Sm] and gadolinium [Gd]. That denominator is abbreviated "Eu*.") In contrast, the biotite-bearing granite from borehole W12309, which contains only trace amounts of magnetite and ilmenite, has low overall REE abundances and exhibits a weak Eu anomaly (Eu/Eu* = 0.86; fig. 7*B*). Samples of the augite- and hornblende-bearing granodiorite in borehole W12497 have consistently higher and highly consistent REE abundances across the ~164-ft sample interval (n=9; fig. 7*B*). This is interpreted as the product of magmatic homogeneity. These samples have weak Eu anomalies (Eu/Eu* = 0.74–0.91), indicating minimal fractionation and loss of plagioclase. This rock contains enough magnetite to be discerned in whole-rock powder X-ray diffraction analyses (1–2 weight percent; Deasy and others, 2024b). Taken together, this evidence suggests that each of these three boreholes penetrated discrete intrusions, each with its own petrogenetic history, rather than a single large pluton as previously hypothesized.

The Gaskin intrusive complex (Zg) is nonconformably overlain by coastal plain strata. It may have once also have been covered by the North Florida volcanic series (€Znf) and (or) Suwannee basin rocks, as both units surround the Gaskin intrusive complex (Thomas and others, 1989; Guthrie and Raymond, 1992). However, step-heated $^{40}Ar/^{39}Ar$ analysis of K-feldspar concentrates from the Gaskin "type" granite in borehole W12509 demonstrate cooling below Ar closure (~150 °C) by 540 Ma and confirm this rock was not thermally reset by later burial (Deasy and McAleer, 2022). It is therefore possible that the Gaskin intrusive complex was not completely covered by the North Florida volcanic series (€Znf) or the Suwannee basin rocks, that is, that inselberg(s) supported by the Gaskin intrusive complex persisted perhaps until coastal plain sedimentation.

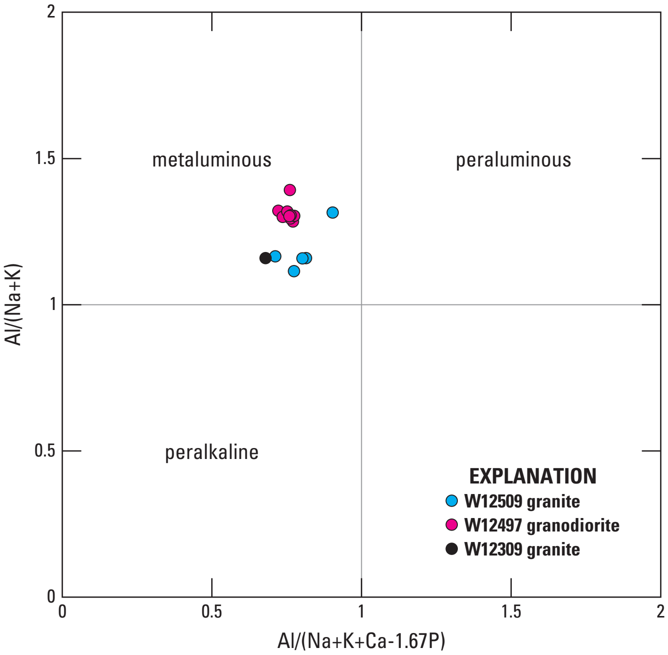


Figure 6. Aluminum index plot of Gaskin intrusive complex (Zg) granitoids from three boreholes (W12509, W12497, and W12309). Field boundaries are from Shand (1943). Geochemical data are from Deasy and others (2024a). Abbreviations: Al, aluminum; Ca, calcium; K, potassium; Na, sodium; P, phosphorus.

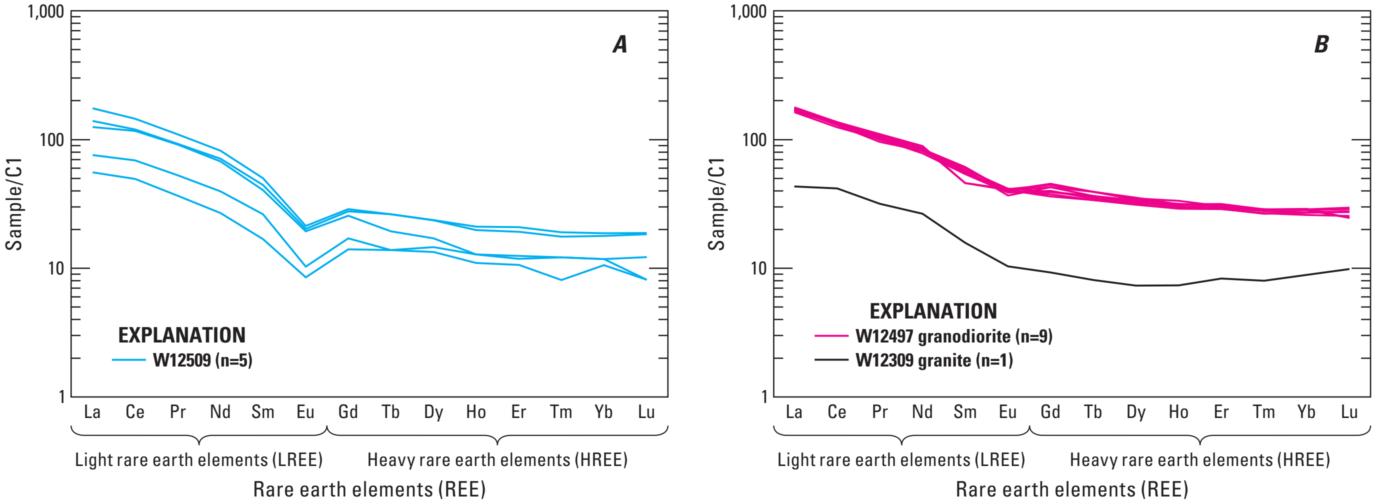


Figure 7. Graphs showing chondrite-normalized rare earth element patterns for Gaskin intrusive complex (Zg) granitoids, including (*A*) Gaskin "type" granite from borehole W12509 and (*B*) hornblende-bearing granodiorite from borehole W12497 and biotite-bearing granite from borehole W12309. Geochemical data are from Deasy and others (2024a). Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; n, number of samples; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

St. Lucie Metamorphic Complex

The St. Lucie Metamorphic Complex (Zsl; Dallmeyer, 1989b; Thomas and others, 1989), also referred to as the "Cowles metamorphic rocks" (Chowns and Williams, 1983), is known from three boreholes in southeastern Florida that penetrated high-grade (amphibolite facies) metamorphic rocks. It is named for St. Lucie County, where two of the three boreholes were drilled. One borehole (W4323) penetrated a diverse range of rock types, including foliated amphibolite, biotite schist, gneissic hornblende-quartz diorite, and the greenschist facies (chlorite zone) retrograde equivalents of those rocks (Bass, 1969; Milton and Grasty, 1969). Hornblende-bearing but otherwise undescribed rocks were also recovered from boreholes W13082 and W14960 (Dallmeyer, 1989b). A massive hornblende-quartz diorite sill and associated biotite hornfels from borehole W1118 were once included in this unit (Applin, 1951). Although available geochronological and thermochronological results (Muehlberger and others, 1966; Bass, 1969) are permissive of this correlation, the identification of a volcanic or volcaniclastic protolith for the hornfels has prompted Chowns and Williams (1983) to include the rocks from borehole W1118 with the younger North Florida volcanic series (ꞒZnf), an interpretation that is followed here. The abundances of major-element oxide analyses of granite and diorite from borehole W4323 (Milton and Grasty, 1969) suggest a calc-alkaline affinity for those intrusive rocks (fig. 8). No data on the provenance or depositional history of the metasediments are available; there are also no geochronological constraints on the primary crystallization of the meta-igneous rocks. Step-heated ^{40}Ar/^{39}Ar analyses of hornblende concentrates from boreholes W14960 and W13082 yield cooling ages of 513.1±1.8 Ma and 510.8±1.1 Ma, respectively (Dallmeyer, 1989b). Whole-rock K-Ar and Rb-Sr age data (Bass, 1969) are scattered but similarly support a Cambrian post-metamorphic cooling history. The similarity of these cooling ages with those of amphibolites in the Rokelide region of Sierra Leone is the basis of a hypothesized tectonic correlation (Chowns and Williams, 1983; Dallmeyer, 1989b, c). Results of whole-rock K-Ar analyses of dioritic and granitic rocks from borehole W4323 have been reported to represent Late Triassic and Permian crystallization ages, respectively (Milton and Grasty, 1969); however, we interpret these data to reflect a mixture of the cooling ages of multiple magmatic mineral populations and the much later crystallization of clays and other alteration minerals.

Osceola Arc

The Osceola arc (informal name of Boote and others, 2018) is a late Neoproterozoic to Cambrian volcanic arc. It is composed of the Osceola intrusive complex (ꞒZo) and the North Florida volcanic series (ꞒZnf).

Osceola Intrusive Complex

Eight boreholes in central peninsular Florida have penetrated granitic rock. Together, these represent the Osceola intrusive complex (ꞒZo), which previously has been referred to as the Osceola granite (Dallmeyer and others, 1987; Thomas and others, 1989) and Osceola granite complex (Heatherington and others, 1996). The Osceola intrusive complex is named for Osceola County, in which the best studied sample from this complex occurs. Available geochemistry identifies metaluminous (fig. 9) granitic and granodioritic rocks with major-element abundances indicative of a calc-alkaline fractionation history (fig. 8). Trace-element abundances are available for rocks from two of these boreholes. In chondrite normalized REE plots (fig. 10), samples of granodiorite from borehole W1014 have moderate light rare earth element (LREE, that is, lanthanide elements with atomic numbers less than 62) enrichment relative to heavy rare earth element (HREE, that is, lanthanide elements with atomic numbers 62 and greater) abundances (La/Yb = ~5) and no Eu anomaly. A sample of granite (W11771) has overall higher REE abundances, with a more pronounced LREE enrichment (La/Yb = 8.8) and a moderate Eu anomaly (Eu/Eu* = 0.63). These results suggest the Osceola intrusive complex is a composite unit comprising an unknown number of discrete granitoids.

A late Neoproterozoic crystallization age (554±13 Ma) is interpreted from U-Pb zircon analyses of granodiorite (borehole W1014; Deasy and others, 2023; compare with Mueller and others, 1994). A Cambrian crystallization age (522.9±6.9 Ma) is reported for a granodiorite from an offshore borehole in the Sarasota arch (Ehrlich and Pindell, 2021). Similar ages are tentatively assumed for other rocks of the Osceola intrusive complex. A K-feldspar separate from a granite in borehole W11771 yielded climbing ^{40}Ar/^{39}Ar age spectra interpreted as recrystallization and cooling through Ar closure (~150 °C) at 470–460 Ma (Deasy and others, 2023).

North Florida Volcanic Series

The North Florida volcanic series (ЄZnf) underlies much of northern Florida (Coleman and Stewart, 1982; Duncan, 1998). It is in contact along its southern flank with the coeval Osceola intrusive complex (ЄZo). It is partially overlain by sedimentary rocks of the Suwannee basin. Volcanic and sedimentary rocks are interleaved in some boreholes (for example, boreholes W15489 and W1118; Duncan, 1998), indicating that volcanic activity overlapped with the onset of Suwannee basin sedimentation. Volcanic rocks in southeastern Georgia and southern Alabama have been tentatively correlated with the North Florida volcanic series (Chowns and Williams, 1983; Guthrie and Raymond, 1992; Heatherington and others, 1996). There, the underlying unit or units are unknown but may include the Gaskin intrusive complex and (or) related Gondwanan rocks.

All rocks of the North Florida volcanic series (ЄZnf) have been altered at lower greenschist facies conditions and contain significant weight percentages of secondary chlorite, sericite, prehnite, actinolite, andradite, and (or) epidote (Deasy and others, 2024b). Other common low-temperature alteration minerals include illite, calcite, and pyrite. Alteration occurred under static conditions; metamorphic foliations have not been identified. Eleven boreholes have penetrated rocks of the North Florida volcanic series. Whereas most boreholes penetrated a single extrusive rock type, samples of both basaltic and rhyolitic rock were recovered from borehole W1473. Borehole W11530 penetrated over 450 ft of compositionally uniform welded andesitic tuff (figs. 11–13; Deasy and others, 2026b, figs. 70–84). A minor component of fragments of altered diabase among the borehole W11530 cuttings increases in the deepest intervals and is interpreted as younger dikes of the Osceola arc system. Contact between tuff and a ~1-millimeter (mm)-thick dike was observed in one fragment (Deasy and others, 2026b, fig. 77). Other examples of intrusive rocks in this unit include phenocryst-dense hypabyssal rhyolite from borehole W1746A. “Red granite” reported in nearby borehole W15281 is also interpreted to be hypabyssal rhyolite (Deasy and others, 2026b, fig. 93; compare with description in Williams and others, 2016). Additionally, in borehole W1118, a dioritic sill intrudes volcanic or volcaniclastic rock of the North Florida volcanic series which is metamorphosed to biotite hornfels (Bass, 1969).

Rocks of the North Florida volcanic series (ЄZnf) have compositions ranging from basaltic to rhyolitic, with a significant population of intermediate compositions, as evidenced by both major-element (fig. 11*A*) and trace-element (fig. 11*B*) discrimination diagrams. A calc-alkaline affinity is indicated by the relative abundances of alkalis, iron, and magnesium (fig. 12). Trace-element ratios suggest rocks of the North Florida volcanic series originated in a continental margin arc (fig. 13). All rock types have overlapping REE abundances but are distinguished by the following characteristics: (1) mafic rocks are weakly enriched in LREE relative to HREE (La/Yb = 4.0–6.8) and exhibit no Eu anomalies (fig. 14*A*); (2) intermediate rocks have La/Yb = 8.3–17.5 and weak Eu anomalies (Eu/Eu* = 0.78–0.94; fig. 14*B*), indicating minor fractionation and loss of plagioclase; and (3) felsic rocks have LREE enrichment similar to the mafic rocks (La/Yb = 4.2–11.5) and Eu/Eu* values similar to the intermediate rocks (0.71–0.91; fig. 14*C*). These data indicate that the samples representing this unit cannot be directly petrogenetically related. This suggests that the magmatic system of the North Florida volcanic series was composed of multiple discrete magmatic pulses and plumbing systems. Felsic volcanic rocks encountered in deep boreholes in southern Alabama that have been correlated with the North Florida volcanic series have Eu/Eu* values of 0.50–0.65 (Fig. 14*D*), indicating stronger plagioclase fractionation than is recorded in rocks of the North Florida volcanic series in Florida. Geochemical similarities between the Florida and Alabama sample suites are otherwise permissive of the correlation, but geochronological and thermochronological constraints on the age(s) of the Alabama volcanics are currently unavailable.

U-Pb analyses of zircons from an altered dacite from borehole W1482 support a crystallization age of 552±8 Ma (Heatherington and others, 1996). An identical age (552±21 Ma; Amoco Corporation unpublished data, as cited in Duncan [1998]) was found by whole-rock K-Ar analysis of volcanic cuttings directly underlying the informal Pumpkin Swamp formation (Duncan, 1998) of the Suwannee basin in borehole W15489. Step-heated ^{40}Ar/^{39}Ar analysis of sericite from the dacite (W1482) indicates recrystallization, probably driven by volcanic hydrothermal activity, through the Cambrian and continuing into the Early Ordovician (Deasy and others, 2023). Similar ages of eruption and alteration are presumed for other rocks in the unit. This crystallization and cooling history is identical to that of the Osceola intrusive complex. Therefore, the Osceola intrusive complex and the North Florida volcanic series are interpreted as the intrusive and extrusive components, respectively, of a single volcanic arc.

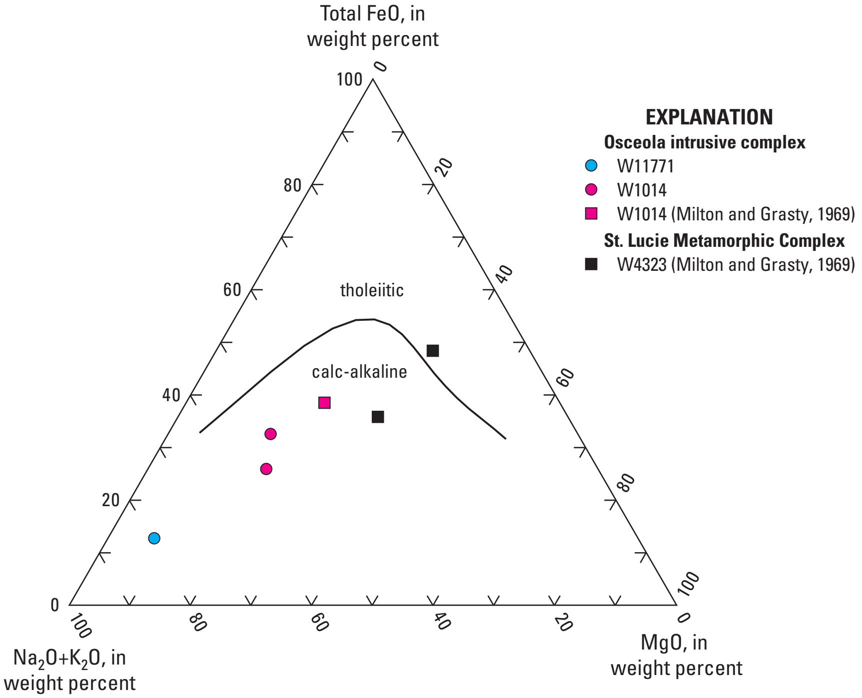


Figure 8. Total alkali-iron-magnesium diagram of whole-rock analyses of rocks in the St. Lucie Metamorphic Complex (Zsl) and the Osceola intrusive complex (ЄZo) from three boreholes (W11771, W1014, and W4323). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Fe, iron; K, potassium; Mg, magnesium; Na, sodium; O, oxygen.

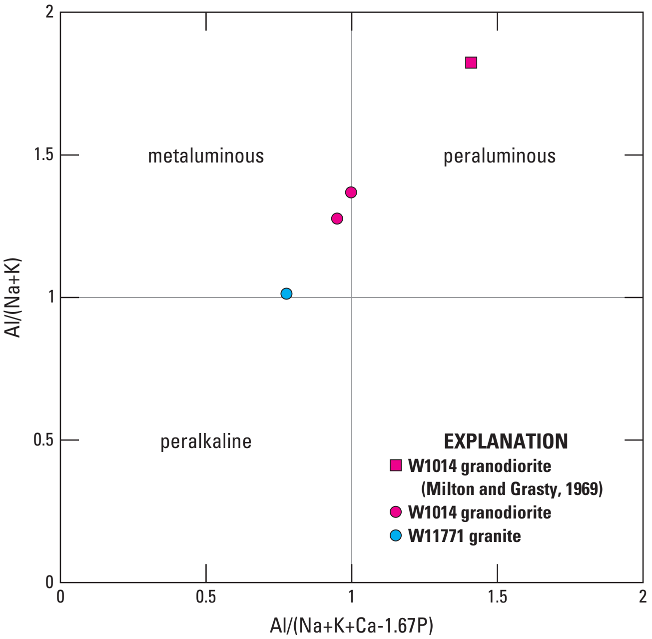


Figure 9. Aluminum index plot of Osceola intrusive complex (ЄZo) granitoids from two boreholes (W1014 and W11771). Field boundaries are from Shand (1943). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Al, aluminum; Ca, calcium; K, potassium; Na, sodium; P, phosphorus.

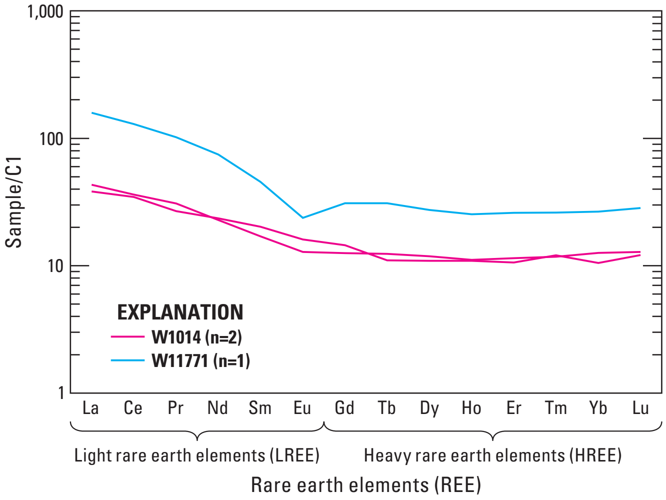


Figure 10. Graph showing chondrite-normalized rare earth element patterns for Osceola intrusive complex (ЄZo) granitoids from two boreholes (W1014 and W11771). Geochemical data are from Deasy and others (2024a). Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; n, number of samples; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

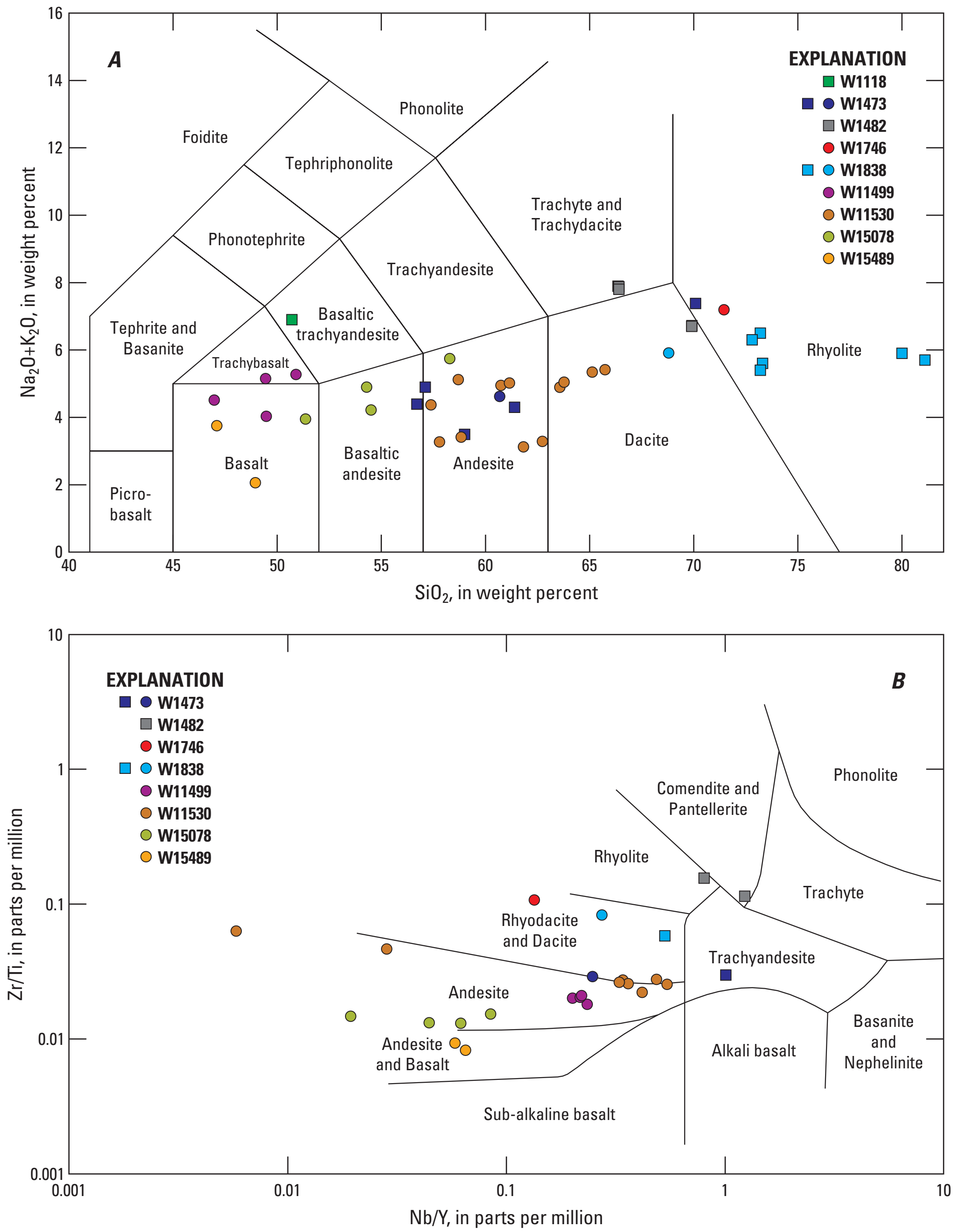


Figure 11. Major-element (*A*) and trace-element (*B*) discrimination diagrams showing the compositions of North Florida volcanic series rocks (€Znf) from nine boreholes (W1118, W1473, W1482, W1746, W1838, W11499, W11530, W15078, and W15489). Field boundaries in part *A* are from Le Bas and others (1986); field boundaries in part *B* are from Winchester and Floyd (1976). Filled circles are data from Deasy and others (2024a). Square symbols for borehole W1118 are data from Milton and Grasty (1969). Square symbols for borehole W1473 are data from Milton and Grasty (1969), Mueller and Porch (1983), and Heatherington and others (1996). Square symbols for borehole W1482 are data from Mueller and Porch (1983) and Heatherington and others (1996). Square symbols for borehole W1838 are data from Milton and Grasty (1969), Mueller and Porch (1983), and Heatherington and others (1996). Abbreviations: K, potassium; Na, sodium; Nb, niobium; O, oxygen; Si, silicon; Ti, titanium; Y, yttrium; Zr, zirconium.

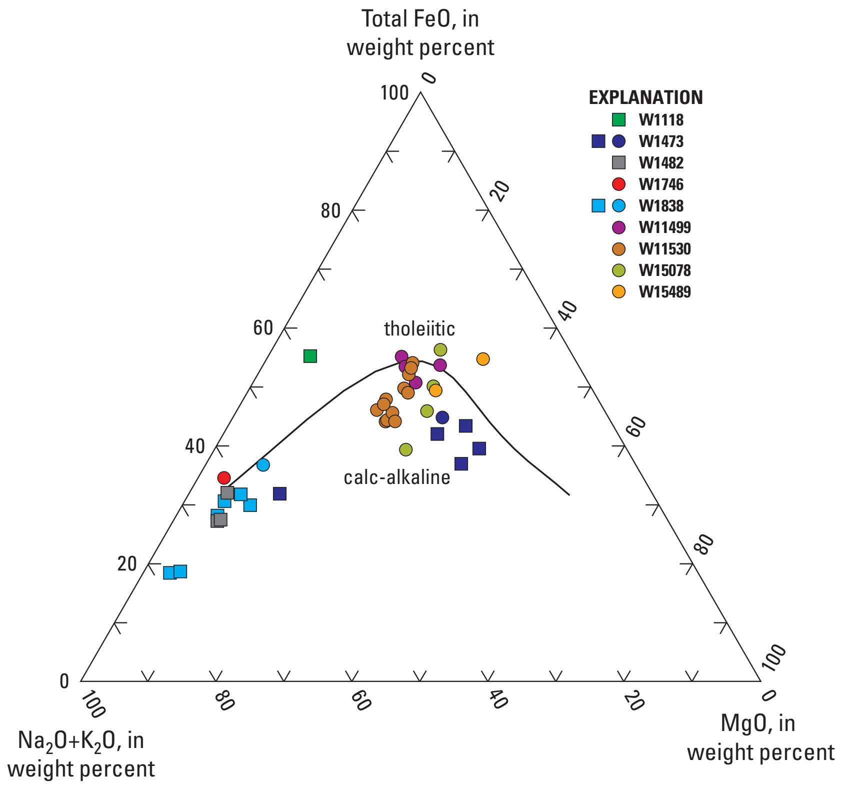


Figure 12. Total alkali-iron-magnesium diagram of whole-rock analyses of North Florida volcanic series rocks (ЄZnf) from nine boreholes (W1118, W1473, W1482, W1746, W1838, W11499, W11530, W15078, and W15489). Filled circles are data from Deasy and others (2024a). Square symbols for borehole W1118 are data from Milton and Grasty (1969). Square symbols for borehole W1473 are data from Milton and Grasty (1969), Mueller and Porch (1983), and Heatherington and others (1996). Square symbols for borehole W1482 are data from Mueller and Porch (1983) and Heatherington and others (1996). Square symbols for borehole W1838 are data from Milton and Grasty (1969), Mueller and Porch (1983), and Heatherington and others (1996). Abbreviations: Fe, iron; K, potassium; Mg, magnesium; Na, sodium; O, oxygen.

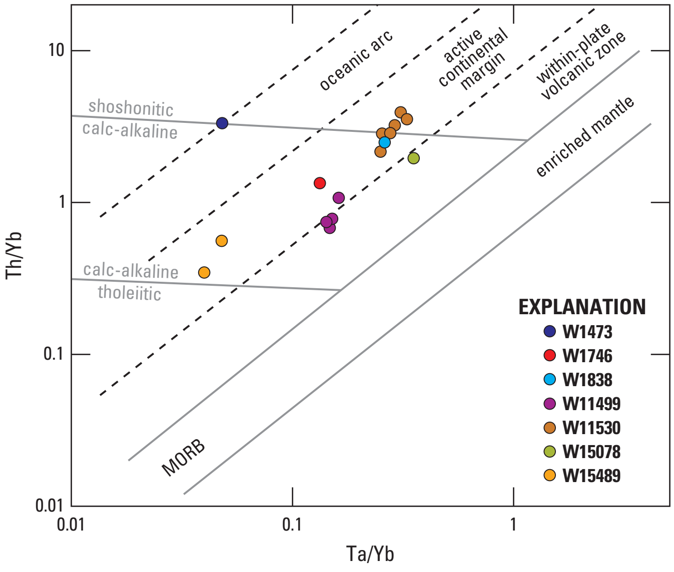


Figure 13. Trace-element-ratio tectonic discrimination diagram (from Gorton and Schandl, 2000) for North Florida volcanic series rocks (ЄZnf) from seven boreholes (W1473, W1746, W1838, W11499, W11530, W15078, and W15489). Abbreviations: MORB, mid-ocean ridge basalt; Ta, tantalum; Th, thorium; Yb, ytterbium.

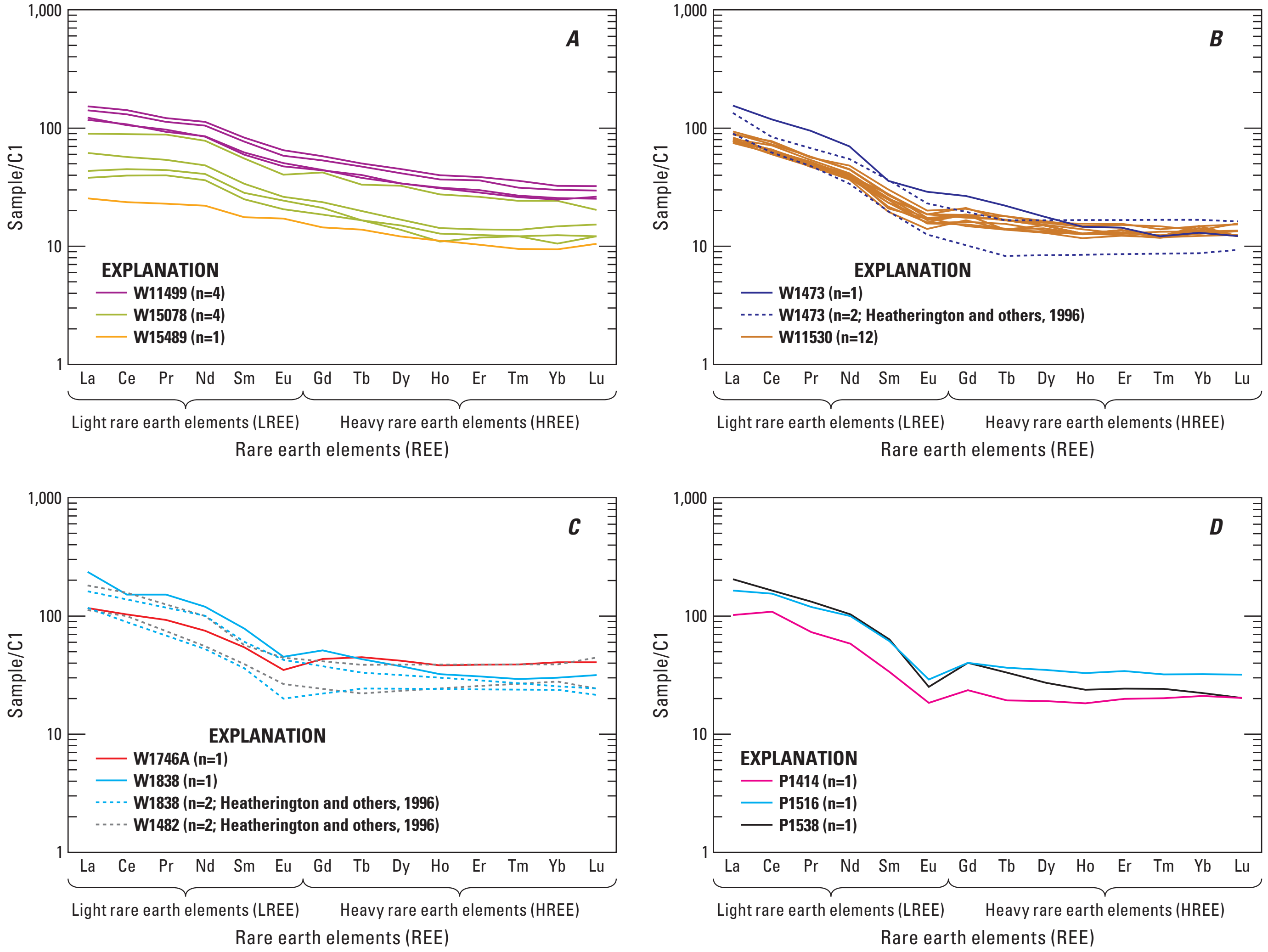


Figure 14. Graphs showing chondrite-normalized rare earth element patterns for North Florida volcanic series rocks (ЄZnf). These rocks include (*A*) basaltic rocks (boreholes W11499, W15078, and W15489), (*B*) intermediate rocks (boreholes W1473 and W11530), (*C*) felsic intrusive rocks (boreholes W1746A, W1838, and W1482), and (*D*) felsic volcanic rocks (boreholes P1414, P1516, and P1538, all of which are from southern Alabama and have been correlated with the North Florida volcanic series). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; n, number of samples; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

Suwannee Basin

The Paleozoic Suwannee basin (informal name of King, 1961) has also been called the “North Florida basin” (Duncan, 1998). The Suwannee basin extends from north-central Florida northward into Georgia and westward through the Florida panhandle and into Alabama (fig. 2). Early stratigraphic correlations of Suwannee basin strata across Florida and adjacent areas in Georgia and Alabama are based on petrographic observations of core and cuttings from boreholes (Campbell, 1939; Bridge and Berdan, 1951; Carroll, 1963). Duncan (1998) discriminates proposed formations and identifies a series of northeast-trending folds within the basin, after which the current map contacts have been modified. The Paleozoic sedimentary sequence as described by Duncan (1998) includes the following units in ascending order: (1) continental feldspathic and lithic-rich sandstones of the informal Pumpkin Swamp formation (Єps, Cambrian); (2) feldspathic sandstone of the informal Cooks Hammock formation (OЄch, Cambrian to Ordovician); (3) the informal Cherry Lake formation (OЄcl, Cambrian to Ordovician), which has a lower quartz arenite unit and an upper feldspathic sandstone-shale sequence interbedded with oolitic ironstone; (4) quartz arenite, shale, and quartz wacke of the informal Smith formation (Os, Middle Ordovician); (5) black shale of the informal San Pedro Bay shale (DSsp, middle Silurian to Lower

Devonian); and (6) undifferentiated marine and terrestrial strata (Du, Middle Devonian). Unnamed unconformities are recognized between the Cherry Lake formation (O€cl) and Smith formation (Os) and between the Smith formation and San Pedro Bay shale (DSsp). The intercalation of the lower strata of the Pumpkin Swamp formation (€ps) with volcanic rocks of the North Florida volcanic series (€Znf) indicates overlapping depositional histories of these units and supports a Cambrian age for onset of Suwannee basin deposition. Ordovician to Devonian ages are supported for the rest of the Suwannee sequence by biostratigraphic evidence (Richards, 1948; Howell and Richards, 1949; Kjellesvig-Waering, 1955; Pojeta and others, 1976). Fossil data (Goldstein and others, 1969; Cramer, 1973), along with paleomagnetic studies (Opdyke and others, 1987) and geochronological studies (Chowns and Williams, 1983; Dallmeyer, 1987; Ehrlich and Pindell, 2021) support a Gondwanan or peri-Gondwanan depositional setting for these rocks.

Suwannee basin strata probably once covered (nonconformably) some, if not all, of the Gaskin and Osceola intrusive complexes (Zg and €Zo, respectively). However, in every borehole that penetrated granitoid rock, the granitoid is directly overlain by lower Mesozoic rift-related clastic sedimentary rocks and porphyritic rhyolites (J₸b) or coastal plain sediments. If the Suwannee basin strata were eroded prior to reburial in these locations, the timing of that erosion is coarsely constrained by early Paleozoic cooling ages in the plutonic rocks and early Mesozoic ages of overlying strata. It is also possible that the Gaskin and Osceola intrusive complexes supported topographic highs (for example, drainage divides) throughout the Paleozoic that were never covered by sediments. This hypothesis is compatible with the observation that the youngest (Devonian) strata have terrestrial and marine depositional environments to the northwest and to the east, respectively, of the Gaskin intrusive complex (Pojeta and others, 1976).

Alleghanian Granitoids

Two syn- to post-tectonic Alleghanian plutons are recognized in northwestern Florida: the informal Fox Creek granite (Pfcg; Winston, 1992) and a smaller, unnamed granodiorite (Pg). These rocks are geochemically distinct from rocks of the Gaskin intrusive complex (Zg) in having dominantly peralkaline compositions (fig. 15), whereas all samples from the Gaskin intrusive complex have metaluminous compositions (fig. 6). Furthermore, the Alleghanian granitoids consistently have very low Eu/Eu* values (0.16–0.38; fig. 16) in contrast to the moderate to absent Eu anomalies in rocks of the Gaskin intrusive complex (fig. 7).

Fox Creek Granite

The Fox Creek granite (Pfcg) is observed in cuttings from two boreholes, one in northwestern Florida (W16298) and one in southwestern Georgia (G3001, not shown on map). It is a massive, coarse-grained, peralkaline granite (fig. 15) enriched in LREE relative to HREE (La/Yb = 7.5–16.5) and with strong Eu anomalies (Eu/Eu* = 0.16–0.38; fig. 16). The latter indicates significant fractionation and loss of plagioclase prior to emplacement. A region of low gravity and high magnetic anomalies south of and including the Florida-Alabama-Georgia border (figs. 4 and 5) is interpreted to represent the subcrop extent of the Fox Creek granite. Zircons extracted from cuttings from both boreholes that penetrate this granite yielded U-Pb sensitive high-resolution ion microprobe (SHRIMP) ages of 296±4 Ma and 294±6 Ma, which are interpreted as the crystallization age of the granite (Heatherington and others, 2010).

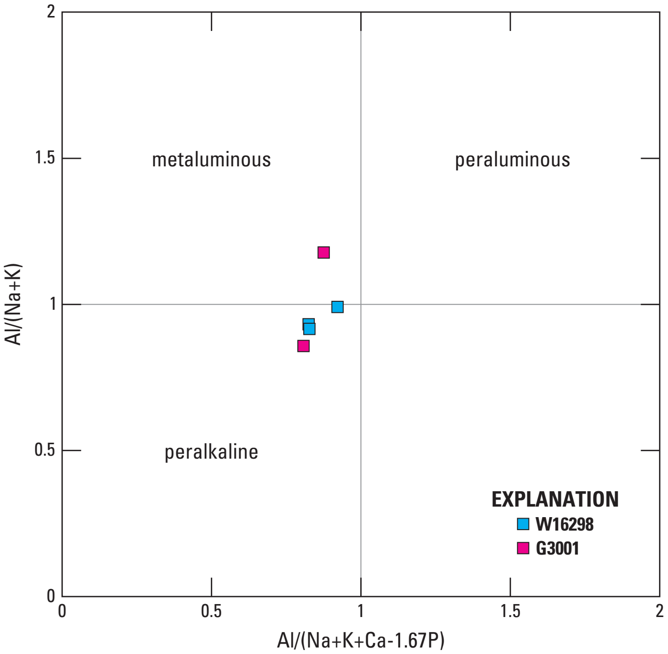


Figure 15. Aluminum index plot of the Permian Fox Creek granites (Pfcg) from two boreholes (W16298 and G3001). Field boundaries are from Shand (1943). Geochemical data are from Heatherington and others (2010). Borehole G3001 is in southwestern Georgia and is not shown on the geologic map. Abbreviations: Al, aluminum; Ca, calcium; K, potassium; Na, sodium; P, phosphorus.

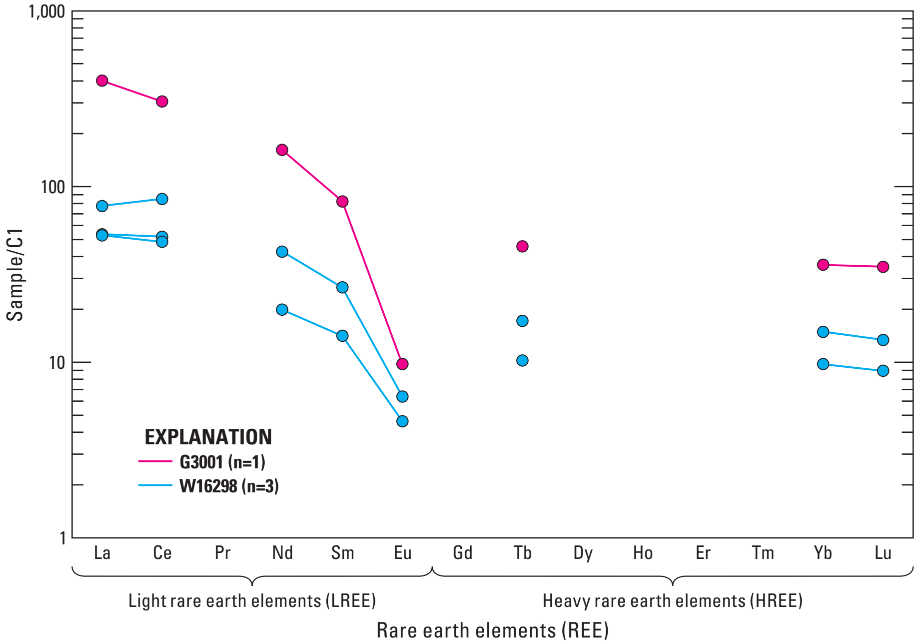


Figure 16. Graph showing chondrite-normalized rare earth element patterns for the Fox Creek granite (Pfcg) from two boreholes (G3001 and W16298). Geochemical data are from Heatherington and others (2010). Borehole G3001 is in southwestern Georgia and is not shown on the geologic map. Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

Unnamed Granodiorite

A separate, smaller body, represented by cuttings from one borehole in the Florida panhandle (W12498), is a massive, gray to pink, coarse-grained, biotite-bearing granodiorite (Pg) containing ~45 percent plagioclase, ~30 percent quartz, and ~18 percent alkali feldspar. The rock is partially altered to chlorite, sericite, and epidote (Deasy and others, 2026b, figs. 14–16). Step-heated ^{40}Ar/^{39}Ar analyses of K-feldspar separates from the granodiorite yield climbing age spectra that indicate Triassic cooling (Deasy and McAleer, 2022). This thermal history is distinct from that of the surrounding Gaskin intrusive complex (Zg) but is compatible with that of the nearby Fox Creek granite (Pfcg). On this basis, a Permian crystallization age is inferred.

Early Mesozoic Rift-Related Rocks

Early Mesozoic rift-related rocks that subcrop in Florida include early Mesozoic (Triassic to Early Jurassic) basins containing undifferentiated clastic sedimentary rocks and porphyritic rhyolites (JTRb), the Early Jurassic North Florida tholeiites (Jt; informal name of Arthur, 1988), and the Late Triassic to Early Jurassic Southwest Florida volcanic province (JTRsf; informal name of Heatherington and Mueller, 2003).

Clastic Sedimentary Rocks and Porphyritic Rhyolites, Undifferentiated

The early Mesozoic undifferentiated clastic sedimentary rocks and porphyritic rhyolites (JTRb) that subcrop in northwestern Florida are extensions of the South Georgia rift system (fig. 2) and include the Conecuh half-graben, the Valdosta basin, and other unnamed outlying rift basins. They contain arkosic sedimentary rocks and felsic volcanic rocks of the Newark Supergroup, including the Eagle Mills Formation, and are commonly intruded by dikes and sills of the North Florida tholeiites (Jt). The subbasins have dominantly half-graben structures bounded by northeast-trending normal faults. The subbasins are truncated by northwest-trending faults that have been interpreted as Late Triassic to Early Jurassic transfer faults coeval with subbasin formation (Heffner, 2013) and as younger normal faults related to Early to Late Jurassic tensional stresses (Hutley, 1985); these interpretations are not mutually exclusive, as reactivation of faults is common. Across Georgia and South Carolina, the polarity of the detachment faults bounding the subbasins alternates across the transfer zones between northwest dipping and southeast dipping (Heffner, 2013). The extension of that pattern into Florida is compatible with geophysical and borehole data. The Conecuh half-graben (Hutley, 1985) subcrops in the northwestern corner of Florida on the northwest flank of the Pensacola-Chattahoochee arch (refer to map) and is bound on the southeast by the Blackwater fault. The Valdosta basin (refer to map) (refer to Barnett, 1975, and Heffner, 2013), also known as the Tallahassee half-graben (Duncan, 1998), subcrops in the northern part of the State and extends into Georgia. An unnamed half-graben within the Pensacola-Chattahoochee arch, north-northwest of Panama City (refer to map), was first identified in seismic data by Arden (1974). Barnett (1975) identifies the Eagle Mills Formation in cuttings from three boreholes in the northern part of the half-graben (refer also to Frederick and others, 2020). Felsic volcanic rocks recovered from three boreholes in the southern part of this structure, including borehole W12309 (Deasy and others, 2026b, figs. 12–13), are correlated with other early Mesozoic volcanic rocks on the basis of similar textures, compositions, and degrees of alteration. Therefore, the half-graben structure is interpreted as another early Mesozoic subbasin of the South Georgia rift system (fig. 3). The large unnamed basin that subcrops under Apalachicola (refer to map) may once have extended to the east to include the smaller unnamed and irregularly shaped basin to the southeast of the Valdosta basin which, if so, may have been uplifted, dissected, and eroded prior to coastal plain sedimentation.

North Florida Tholeiites

The North Florida tholeiites (Jt) are a group of basaltic dikes, sills, and lava flows (Arthur, 1988; Heatherington and Mueller, 1999, 2003). Major-element compositions of these rocks define a tholeiitic fractionation trend (fig. 17; Arthur, 1988). Samples of the North Florida tholeiites (Jt) define systematic variations in the abundances of high field strength elements (HFSE) versus the magnesium number (Mg#, which is the molar ratio of magnesium oxide and combined iron and magnesium oxides [expressed as a percent] and is calculated as follows: 100×MgO/(FeO*+MgO)) (fig. 18). (The term "FeO*" indicates Fe_2O_3 abundances that were recalculated as FeO for petrologic reasons.) The olivine gabbro of borehole W12497 plots along these trends at higher Mg# values and lower HFSE concentrations than the finer grained rocks. Chondrite-normalized ($_N$) REE plots of the gabbro of borehole W12497 have slight LREE enrichment relative to HREE (La_N/Yb_N = 1.4–1.9) and no Eu anomaly (fig. 19). Tholeiites from near the Jay fault in peninsular Florida have higher REE concentrations but similar La/Yb and Eu/Eu* values (fig. 19). Previous work on these rocks revealed a petrogenetic history similar to that of other early Mesozoic tholeiites in eastern North America (Arthur, 1988). Geochemical characteristics, cross-cutting relations, and available geochronology (Grasty and Wilson, 1967) allow the correlation of these rocks with the central Atlantic magmatic province (Marzoli and others, 2017). Isotopic evidence supports derivation from ~1-Ga (giga-annum, billion years before present) continental lithospheric mantle and crust similar to magma sources in the Carolina terrane (Heatherington and Mueller, 1999). These data have been invoked to correlate the Suwannee terrane with the Sunsas-Rondonian or Orinoquian provinces of the South American parts of Gondwana, rather than with African sources.

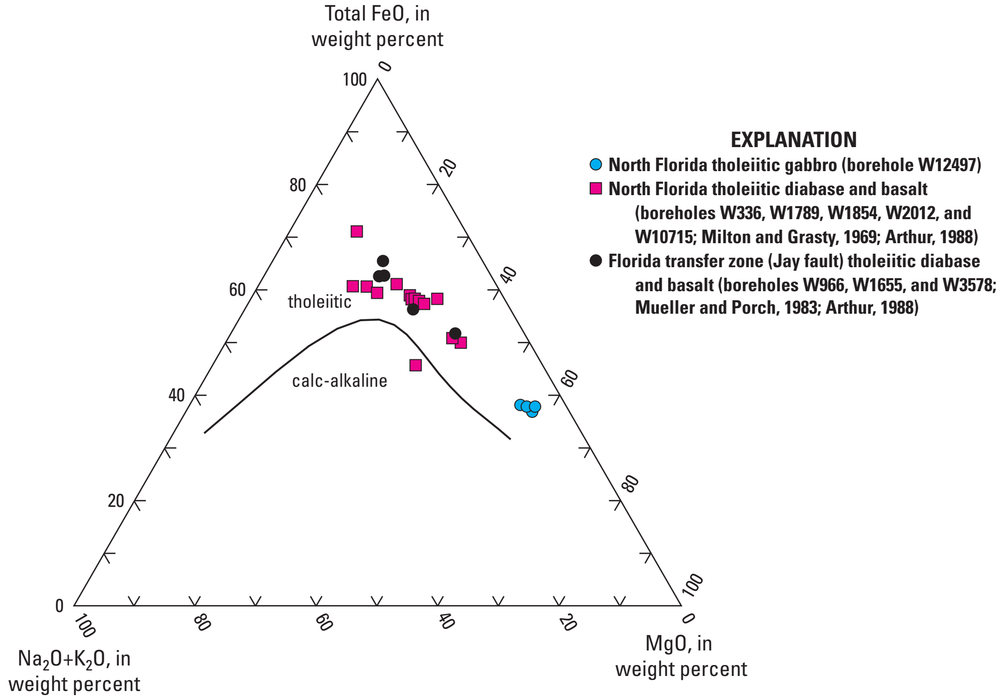


Figure 17. Total alkali-iron-magnesium diagram of whole-rock analyses of North Florida tholeiites (Jt) from nine boreholes (W12497, W336, W1789, W1854, W2012, W10715, W966, W1655, and W3578). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Fe, iron; K, potassium; Mg, magnesium; Na, sodium; O, oxygen.

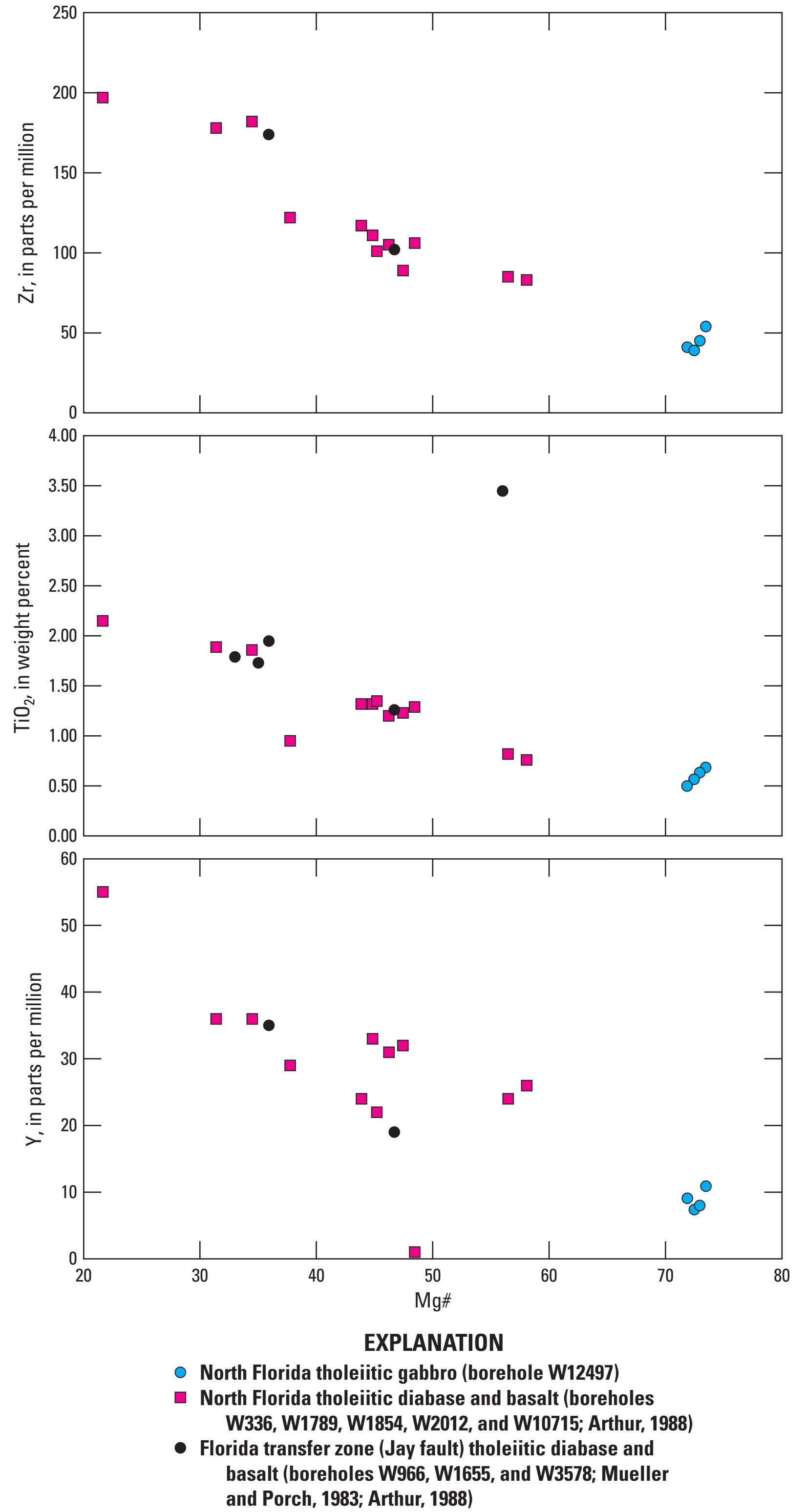


Figure 18. Graphs showing selected high-field-strength elements versus Mg# from whole-rock analyses of North Florida tholeiites (Jt) from nine boreholes (W12497, W336, W1789, W1854, W2012, W10715, W966, W1655, and W3578). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Mg#, the magnesium number (the molar ratio of magnesium oxide and combined iron and magnesium oxides) expressed as a percent; O, oxygen; Ti, titanium; Y, yttrium; Zr, zirconium.

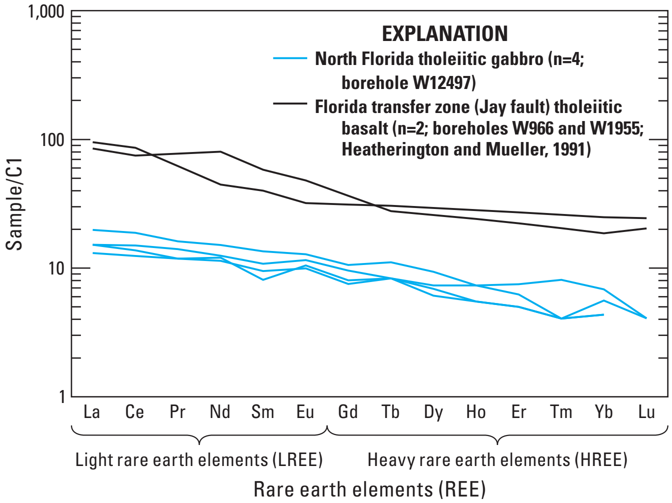


Figure 19. Graph showing chondrite-normalized rare earth element patterns for North Florida tholeiites (Jt) from three boreholes (W12497, W966, and W1955). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; n, number of samples; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

Southwest Florida Volcanic Province

The Southwest Florida volcanic province (JTRsf) subcrops across much of southern Florida and extends west into the Gulf Coastal Plain. Rocks attributed to this unit are represented by samples from 20 boreholes and include mafic to felsic volcanic rocks. Petrographic descriptions and thin section photomicrographs of many of these rocks are available in Applin (1951) and Milton (1972). The three easternmost boreholes were drilled through the Southwest Florida volcanic province into the St. Lucie Metamorphic Complex (Zsl). Underlying units elsewhere are inferred from seismic profiles to include the Osceola arc in south-central Florida and sedimentary rocks of the Suwannee basin in the unit's northwestern extent (Ehrlich and Pindell, 2021).

A largely bimodal distribution of basaltic and rhyolitic compositions (with one intermediate sample) is demonstrated in a total alkalis versus silica diagram (fig. 20), and a calc-alkaline fractionation trend is suggested by whole-rock major-element compositions (fig. 21). Chondrite-normalized REE plots of felsic rocks show moderate LREE enrichment relative to HREE concentrations and slight Eu anomalies (Eu/Eu* = 0.60 and 0.83) showing loss of plagioclase (fig. 22).

Geochronological data for this unit include U-Pb ages of zircon in rhyolite from borehole W12838 which indicate Early Jurassic (Toarcian) crystallization (Ehrlich and Pindell, 2021). The occurrence of North Florida tholeiites (Jt) within the unit necessitates that some rocks of the Southwest Florida volcanic province were deposited in the Late Triassic. This is supported by whole-rock data from three boreholes (W966, W1005, and W1655) which yielded a Rb-Sr isochron age of 240±20 Ma (Heatherington and Mueller, 1991). Whole-rock ^{40}Ar/^{39}Ar analyses of mafic rock from borehole W1655 yielded ages of 192±7 Ma and 196±6 Ma (Mueller and Porch, 1983), whereas samples from the same borehole analyzed by the K-Ar method yielded ages of 143±7 Ma and 147±3 Ma (Milton and Grasty, 1969). The Early Jurassic ages are close to but slightly older than the results from borehole W12838 and may represent a different eruption within the same volcanic package. The Late Jurassic ages, however, are of "highly altered" material (Milton and Grasty, 1969, p. 2487) and probably represent mixed ages that have no geologic significance. Likewise, an amygdaloidal basalt from within the volcaniclastic sequence in borehole W4323 yielded a K-Ar age of 89.3±2.2 Ma (Milton and Grasty, 1969); because of the reported abundance of secondary minerals, we suspect this rock is older and include it and the volcaniclastic rocks with the Southwest Florida volcanic province (JTRsf). Whole-rock K-Ar analyses of granite and diorite underlying the volcaniclastic rocks in borehole W4323 yielded Permian and Triassic ages, respectively (Milton and Grasty, 1969). The Triassic ages have been invoked to correlate the diorite with the Southwest Florida volcanic province. However, we interpret both the Permian and Triassic ages as mixtures of cooling ages and alteration ages and include the plutonic rocks with the St. Lucie Metamorphic Complex (Zsl). Together, these data constrain the age of the Southwest Florida volcanic province (JTRsf) to the Late Triassic to Early Jurassic.

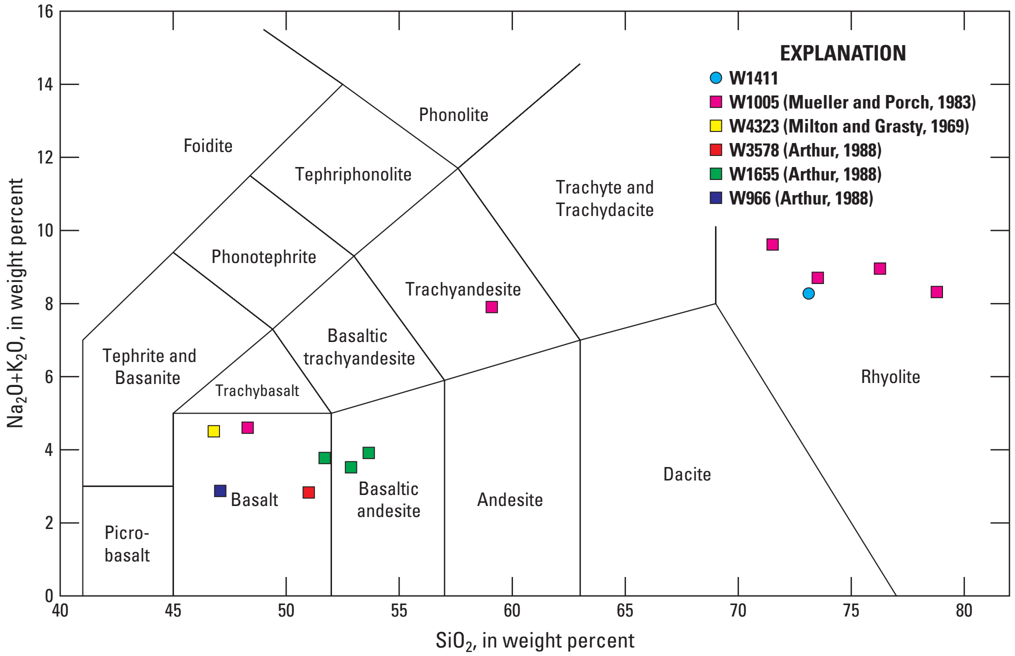


Figure 20. Total alkalis versus silica diagram showing the composition of Southwest Florida volcanic province rocks (JT̅Rsf) for six boreholes (W1411, W1005, W4323, W3578, W1655, and W966). Field boundaries are from Le Bas and others (1986). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: K, potassium; Na, sodium; O, oxygen; Si, silicon.

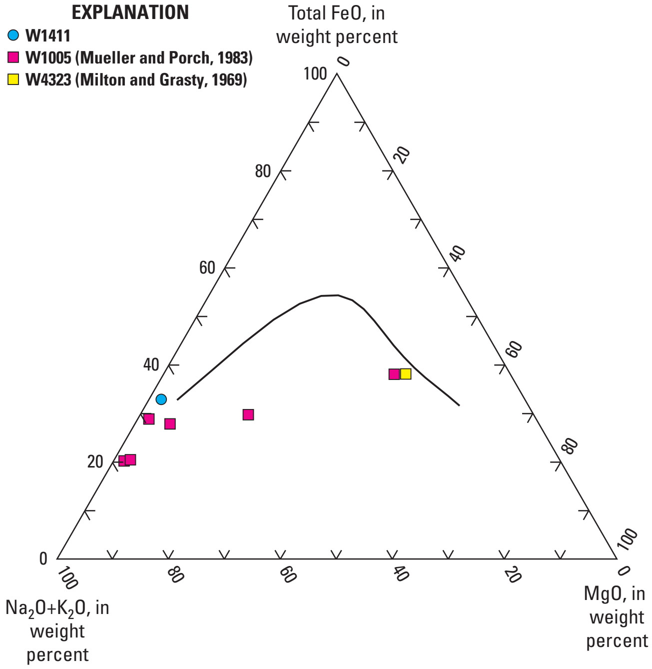


Figure 21. Total alkali-iron-magnesium diagram of whole-rock analyses of Southwest Florida volcanic province rocks (JT̅Rsf) from three boreholes (W1411, W1005, and W4323). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Fe, iron; K, potassium; Mg, magnesium; Na, sodium; O, oxygen.

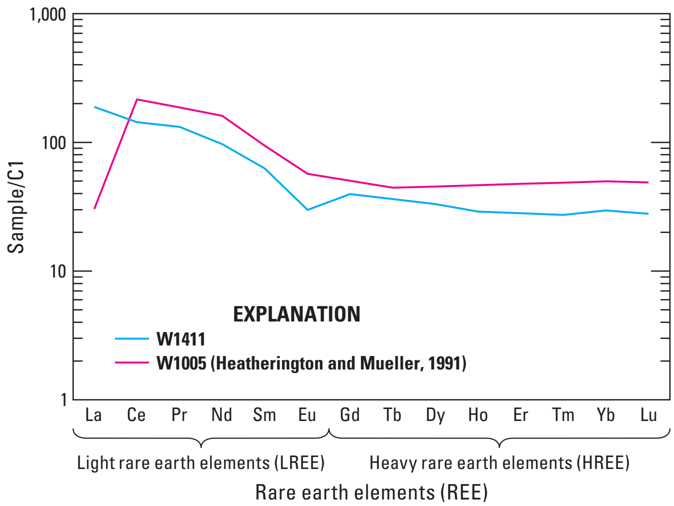


Figure 22. Graph showing chondrite-normalized rare earth element patterns for Southwest Florida volcanic province rocks (JŦRsf) from two boreholes (W1411 and W1005). Geochemical data are from Deasy and others (2024a) unless otherwise indicated. Abbreviations: Ce, cerium; Dy, dysprosium; Er, erbium; Eu, europium; Gd, gadolinium; Ho, holmium; La, lanthanum; Lu, lutetium; Nd, neodymium; Pr, praseodymium; sample/C1, abundance in sample divided by abundance in C1 chondrites; Sm, samarium; Tb, terbium; Tm, thulium; Yb, ytterbium.

Metamorphism

The only basement rocks containing metamorphic fabrics are the high-grade (amphibolite facies) rocks of the St. Lucie Metamorphic Complex (Zsl). ^{40}Ar/^{39}Ar analyses of hornblende from two boreholes (W13082 and W14960) in rocks of the St. Lucie Metamorphic Complex indicate cooling through Ar-closure temperatures (~500 °C) in the Middle Cambrian (510.8±1.1 Ma and 513.1±1.8 Ma, respectively; Dallmeyer, 1989b). This is consistent with the thermal history of Osceola arc rocks, suggesting that the St. Lucie Metamorphic Complex is part of the country rock on which the Osceola arc was built. However, neither the peak metamorphic conditions affecting the St. Lucie Metamorphic Complex nor the timing thereof are constrained quantitatively.

Static alteration of Suwannee terrane rocks at lower greenschist facies or cooler conditions is common and was probably driven by local hydrothermal processes related to volcanic activity. Basalt, basaltic andesite, and dacite of the North Florida volcanic series (ꞒZnf) are pervasively altered to ~30–50 percent alteration minerals including chlorite, epidote, actinolite, prehnite, titanite, and magnetite (Deasy and others, 2024b). Later, lower temperature alteration produced quartz, epidote, and calcite veins and replaced feldspars with fine-grained, randomly oriented illite and (or) kaolinite. In contrast, felsic volcanic rocks of the North Florida volcanic series are relatively unmetamorphosed. Alteration of the felsic rocks is limited to <10 percent illite, kaolinite, hematite, and goethite, with trace amounts of chlorite. Feldspars in rocks of the Osceola intrusive complex (ꞒZo) are commonly partially replaced by epidote and muscovite (sericite). Biotite, where present, is almost completely pseudomorphically replaced by chlorite+ilmenite. Epidote, calcite, dolomite, and quartz veins are common in rocks of the Osceola intrusive complex. Together, alteration minerals compose ~10–25 percent of rocks of the Osceola intrusive complex.

Alteration of the three granitoids of the Gaskin intrusive complex (Zg) investigated in this study (W12309, W12497, and W12509) is highly variable. The muscovite-bearing granite (W12509) is not metamorphosed except for the partial sericitization of plagioclase. Coarse-grained muscovite in cleavage planes within microcline and small amounts of calcite and dolomite precipitated in dissolution pits in feldspars (Deasy and others, 2026b, figs. 18–22) are interpreted as deuteric features. The granite in the western subcrop of the Gaskin intrusive complex (W12309) contains potassium feldspars that are completely replaced by low-temperature "adularia," biotite that is pseudomorphically replaced by chlorite, and minor amounts of illite and kaolinite. ^{40}Ar/^{39}Ar analysis of K-feldspar from this granite indicates recrystallization in the Early Cretaceous (Deasy and McAleer, 2022), probably driven by loading of coastal plain sediments. The granodiorite of the Gaskin intrusive complex that subcrops south of the Tallahassee fault (W12497) is strongly overprinted by globular myrmekitic plagioclase+quartz intergrowths (Deasy and others, 2026b, figs. 30–34 and 37–39). This relatively high-temperature (>450 °C) texture is interpreted to be the result of contact metamorphism driven by the intrusion of the North Florida tholeiite gabbro (Jt) (which was encountered in the same borehole), although thermochronological constraints are not available.

Structure

Basins and Uplifts

The Pensacola-Chattahoochee arch (figs. 1, 4, and 5) is an uplifted block of Neoproterozoic and early Paleozoic Suwannee terrane rocks. It subcrops under much of the Florida panhandle and is bounded by the Blackwater and Tallahassee faults. The Wiggins-Hancock arch (figs. 1, 4, and 5) is a Mesozoic horst that subcrops in the panhandle west of the Jay fault; it is also known as the Wiggins arch (Montgomery, 2000), Wiggins block (fig. 2) (Mueller and others, 2014), and Wiggins uplift (Dallmeyer, 1989a). Hornblende, biotite, and phyllite samples from basement rocks in the Wiggins-Hancock arch in Alabama have late Pennsylvanian ^{40}Ar/^{39}Ar cooling ages (Dallmeyer, 1989a) interpreted as cooling from metamorphism in the early stages of the Alleghanian orogeny. Basement rocks of the Wiggins-Hancock arch have not been sampled in Florida.

Several basins and uplifts in the Gulf Coastal Plain south of the Jay fault are inferred from geophysical data. These include, from northwest to southeast, the Apalachicola-Desoto Canyon basin, the Middle Ground arch/Southern platform, the Tampa basin, the Sarasota arch, and the South Florida basin (figs. 1, 4, and 5). Upper Jurassic or Lower Cretaceous carbonates have been penetrated at depths between ~11,975 and 17,716 ft in the South Florida basin (Florida Geological Survey, 2023); the depth and nature of basement rock in the South Florida basin is unknown. The West Florida terrane (proposed name of Ehrlich and Pindell, 2021) comprises the pre-late Jurassic basement underlying the South Florida basin and the other structures south of the Jay fault. It is distinguished from the Suwannee terrane by the presence of post-Cambrian Paleozoic zircons and is perhaps related to the Maya block (Ehrlich and Pindell, 2021).

The Central Florida uplift, also known as the Peninsular arch, subcrops in the Florida peninsula and brings rocks of the Osceola arc (ꞒZo and ꞒZnf) up against Suwannee basin strata across an unnamed north-northeast-striking normal fault. This uplift is truncated to the south by the Hatchineha fault and to the north by the Lake City fault. The timing of latest uplift is mapped as early Mesozoic, but this fault may have reactivated a structure potentially as old as early Paleozoic (Duncan, 1998).

Folds

Duncan (1998) employed stratigraphy and dipmeter logs (a dipmeter is a device for measuring the orientations of planar structures intersecting a borehole) to identify several broad, open, upright folds in the Paleozoic sedimentary rocks of the Suwannee terrane. The northeasterly trends of these folds run approximately parallel to the Higgins-Zietz line, which may represent the northern extent of the Suwannee terrane (fig. 2; Horton and others, 1984, 1989, 1991; Thomas and others, 1989), suggesting that folding occurred during late Paleozoic assembly of Pangaea. Quantitative constraints on the timing of folding are not available.

The Taylor syncline (Duncan, 1998) is cored by the San Pedro Bay shale (DSsp) and plunges gently to the southwest. The Dixie anticline (Duncan, 1998) is cored by the Cooks Hammock formation. The apparent closure of this fold in the northeast implies a northeastward plunge of the fold axis, in contrast to other folds. The Otter Creek syncline (proposed name), cored by undifferentiated Devonian rocks and San Pedro Bay shale, lies southeast of the Dixie anticline and plunges gently to the southwest. Other smaller, unnamed folds are interpreted to subcrop in the northern part of Florida (contacts modified from Duncan, 1998).

Faults

Several brittle faults are recognized to cut through Florida basement rocks. Two orientations predominate: northeast-trending normal faults (which define the margins of South Georgia rift system subbasins) and northwest-trending sinistral transfer zones. Subbasins of the South Georgia rift system have dominantly half-graben structures, the polarity of which alternates across transfer faults in Georgia and South Carolina (Heffner, 2013). The continuation of this pattern through Florida is supported by borehole data, by reinterpretation of available seismic studies (Arden, 1974), and by reprocessed geophysical data (figs. 4 and 5). All mapped faults are therefore considered to be the products of oblique rifting in the early Mesozoic related to the breakup of Pangaea, although some may follow inherited structures. Reactivation of these faults after the onset of coastal plain sedimentation in the Middle Jurassic is possible but unknown. Historical records of seismicity in Florida are extremely limited (Reagor and others, 1987; U.S. Geological Survey, 2024). Hypothesized associations between proposed faults and historical earthquakes are suggested below.

The Jay fault (Smith 1983, 1993) follows a major lineament that is traceable in geophysical surveys from the Bahamas to Oklahoma; it is also known as the Florida transfer zone (Ehrlich and Pindell, 2021), Bahamas fracture zone (Klitgord and others, 1984), Bahamas transfer zone (Nemčok and others, 2016), and Florida-Bahamas lineament (Beaman and others, 2017). The Jay fault separates the Suwannee and West Florida terranes (fig. 2) and may be the reactivated boundary which originally sutured those terranes (Ehrlich and Pindell, 2021). This major structure may also have originated as a transform fault in the Iapetus Ocean (Thomas, 2010). These hypotheses are not mutually exclusive. Most displacement along this fault is probably Late Triassic to Middle Jurassic (Ehrlich and Pindell, 2021) and broadly contemporaneous with the northeast-striking faults responsible for the South Georgia rift system and related subbasins. Several historical earthquakes near the intersection of the trace of the Jay fault and the Florida-Alabama border (U.S. Geological Survey, 2024) may be associated with recent motion along the Jay fault, but this relationship has not been confirmed.

Another transfer fault northeast of and approximately parallel to the Jay fault truncates the southwestern margin of the Valdosta basin (Heffner, 2013) and is here called the Hatchineha fault. Gravity and aeromagnetic data (figs. 4 and 5) support the projection of this fault through peninsular Florida where it juxtaposes the Osceola intrusive complex (ꞒZo) and the Southwest Florida volcanic province (JTRsf). The Hatchineha fault has northeast-side-down motion in the panhandle and southwest-side-down motion in central and southern Florida, indicating rotational faulting. The Lake City fault (Duncan, 1998) is a right-lateral transfer fault inferred from the truncation of the Taylor syncline and Dixie anticline by a large area of San Pedro Bay shale (DSsp). Approximately 215 m of down-to-the-northeast normal motion is estimated, as well as an unquantified dextral strike-slip component (Duncan, 1998). The Cordele transfer zone (Heffner, 2013) is another northwest-trending sinistral transfer fault in the northeastern part of the State. Normal motion on this fault is possible but unknown. The Cordele transfer zone subcrops approximately 20 km southwest of Jacksonville. Its association with the October 31, 1900, magnitude 3.5 Jacksonville earthquake (U.S. Geological Survey, 2024) is possible but not confirmed.

The Blackwater fault (Duncan, 1998) defines the boundary between the Conecuh half-graben to the northwest and the Pensacola-Chattahoochee arch to the southeast. The Tallahassee fault (Duncan, 1998) defines the southeastern boundary of the Pensacola-Chattahoochee arch as well as, for part of its length, the northwestern margin of the Valdosta basin. Several unnamed, northeast-trending faults in northern and central peninsular Florida, identified by strong linear magnetic and gravity anomaly contrasts (figs. 4 and 5), separate inferred horsts (low gravity, low magnetic response) and grabens (high gravity, high magnetic response; Coleman and Stewart, 1982).

Tectonics

Most of Florida is underlain by rocks of the Suwannee terrane of Gondwanan origin, a correlation that is supported by paleontological (Pojeta and others, 1976), paleomagnetic (Opdyke and others, 1987), and geochronological (Mueller and others, 1994; Heatherington and others, 1996) evidence. Specific correlation of Suwannee basin strata with the Bové basin in present day Sierra Leone is supported by stratigraphic (Duncan, 1998), paleontological (Cramer, 1973), and thermochronological (Dallmeyer, 1987) evidence. Correlation of the Osceola arc (€Znf and €Zo) and the St. Lucie Metamorphic Complex (Zsl) with rocks of the Rokelide orogen, also in Sierra Leone, is supported by thermochronological data (Dallmeyer and others, 1987; Dallmeyer, 1989a, c). However, the isotopic signatures of Mesozoic tholeiites have been invoked to correlate the Suwannee terrane with South American parts of Gondwana (Heatherington and Mueller, 1999, 2003). The discrimination of the Gaskin intrusive complex (Zg) from the Osceola arc on the basis of recent geochronological and thermochronological data (Deasy and McAleer, 2022; Deasy and others, 2023) further complicates terrane correlations. The West Florida terrane, a composite terrane of Amazonian and West African origin inferred from detrital zircons in Mesozoic strata in the Gulf Coastal Plain (Ehrlich and Pindell, 2021), may provide a link. If the Suwannee, West Florida, and perhaps other Gondwanan terranes merged into a single composite terrane before docking to Laurentia during the Alleghanian orogeny, their intercalation at depth may explain the isotopic signatures of the Mesozoic tholeiites. Further research could test this hypothesis.

Map Applications

Possible applications of this map relate to essential mineral, energy, and groundwater resources. The pre-Middle Jurassic basement rocks are much less permeable than overlying sediments composing the coastal plain aquifers. The boundary between pre-Middle Jurassic rocks and overlying coastal plain sedimentary units is thus an important boundary for the flow of groundwater in coastal plain aquifers. Radiogenic, heat-producing granites insulated by coastal plain sediments are potential sources of low-temperature geothermal energy. Buried early Mesozoic rift basins are potential energy resources for natural gas and are also relevant for applications such as deep supercritical carbon dioxide (CO_2) storage. The basement geologic framework is also pertinent for infrastructure and engineering applications such as seismic-hazard assessment and the siting of critical facilities such as nuclear power stations.

DESCRIPTION OF MAP UNITS

[Within map-unit descriptions, rock types are listed in order of decreasing abundance. Similarly, within rock descriptions, minerals are listed in order of decreasing abundance. Terminology for plutonic igneous rocks follows the International Union of Geological Sciences (IUGS) classification (Streckeisen, 1973). Characteristics of geologic map units on airborne gravimetric and aeromagnetic surveys (figs. 4 and 5, respectively) are mentioned where particularly noteworthy]

EARLY MESOZOIC RIFT-RELATED ROCKS

Jt	**North Florida tholeiites (Early Jurassic)—**Informal name of Arthur (1988). Includes basalt, diabase, gabbroic dikes and sills, and basaltic lava flows. Fresh samples are green to black; weathered samples are red from alteration to iron oxyhydroxide(s). Samples from different boreholes are texturally distinct and range from aphanitic to porphyritic with plagioclase and (or) olivine phenocrysts, to diabasic (that is, medium grained, equigranular; may be ophitic), to gabbroic (that is, coarse grained with clinopyroxene oikocrysts much larger than the ~6-millimeter [mm] maximum size of cuttings fragments). Most bodies are intrusive within lower Mesozoic clastic sedimentary rocks and porphyritic rhyolites (JTRb). However, three boreholes in Taylor County penetrate extrusive olivine basalts interleaved with early Mesozoic clastic sedimentary rocks (Arthur, 1988). A subset of vesicular tholeiitic basalts found in south Florida along the Jay fault within the geochemically distinct Southwest Florida volcanic province (JTRsf) may also be extrusive. Tholeiitic basalts also intrude Suwannee basin sedimentary strata in several boreholes. Finally, an intrusion of olivine gabbro into granodiorite of the Gaskin intrusive complex (Zg) (W12497) is included in this unit
JTRsf	**Southwest Florida volcanic province (Early Jurassic to Late Triassic)**—Informal name of Heatherington and Mueller (2003). Includes bimodal mafic and felsic volcanic rocks. Mafic rocks are basaltic in composition, with textures ranging from aphanitic and locally vesicular to plagioclase-phyric porphyries to diabasic and ophitic (Milton, 1972). They are commonly interlayered with shale and (or) carbonate rock and may contain sedimentary xenoliths. Some sedimentary rocks associated with basalts are metamorphosed to hornfels. Some mafic rocks are altered to chlorite, quartz, and other low-grade metamorphic products. Felsic rocks of this unit include buff to tan or green, rusty-weathering porphyritic rhyolite and rhyolitic agglomerate (Applin, 1951; Milton, 1972). Phenocrysts include quartz, plagioclase, and alkali feldspar up to 0.5 mm in diameter in a massive, microcrystalline quartzofeldspathic matrix. Partial alteration under diagenetic to sub-greenschist facies conditions is demonstrated by the occurrence of kaolinite, illite, chlorite, hematite, and goethite
JTRb	**Clastic sedimentary rocks and porphyritic rhyolites, undifferentiated (Jurassic and Triassic)—**Includes rift-facies rocks ascribed to the Newark Supergroup, including the basal Eagle Mills Formation (Applegate and others, 1981; Heffner, 2013; Frederick and others, 2020). The sedimentary component is dominated by hematite-stained, arkosic and lithic sandstones and conglomerates (red beds) with minor red and green mudstone. The volcanic rocks are quartz- and potassium (K)-feldspar-phyric porphyries with fine-grained, hematite-stained quartzofeldspathic matrices; flow/compaction structures (for example, fiamme) and sedimentary xenoliths are common

ALLEGHANIAN GRANITOIDS

Pfcg	**Fox Creek granite (Permian)**—Informal name of Winston (1992). Includes coarse-grained, massive peralkaline granite containing subequal amounts of plagioclase, quartz, and perthitic feldspar. Uranium-lead (U-Pb) zircon sensitive high-resolution ion microprobe (SHRIMP) ages are 296±4 Ma (mega-annum, million years before present) and 294±6 Ma (Heatherington and others, 2010). A region of low gravity and high magnetic anomalies south of and including the Florida-Alabama-Georgia border (figs. 4 and 5) is associated with the subcrop extent of this unit

Pg	**Granodiorite (Permian)**—Gray to pink, coarse-grained, massive, biotite-bearing granodiorite in which plagioclase is approximately twice as abundant as alkali feldspar. The rock is slightly statically altered to chlorite, sericite, and epidote

SUWANNEE TERRANE

SUWANNEE BASIN

[Siliciclastic rocks of the Suwannee basin (Devonian to Neoproterozoic). Stratigraphic sequence is from Duncan (1998). Formation names are all informal and are from Duncan (1998)]

Du	**Marine and terrestrial strata, undifferentiated (Middle Devonian)**—According to Duncan (1998), unit consists of “alternating dusky to gray-red and dark-gray to black mudstones and claystones interbedded with minor amounts of very fine grained, pale to light-green sandstone.” Includes continental and marine strata, undifferentiated. Age is constrained to Middle Devonian by fossil data (Barnett, 1975, p. 135–136, citing Mobil Oil Company paleontology)
DSsp	**San Pedro Bay shale (Lower Devonian to middle Silurian [Wenlock])**—Black shale. Fossil and palynological data constrain the time of deposition from middle Silurian (late Wenlock) to Early Devonian (Lochkovian) (Goldstein and others, 1969; Cramer, 1973; Pojeta and others, 1976; Duncan, 1998)
Os	**Smith formation (Ordovician)**—Quartz arenite, shale, and quartz wacke, undifferentiated. A Middle Ordovician age is constrained by chitinozoans (Duncan, 1998)
O€cl	**Cherry Lake formation (Ordovician to Cambrian)—**Quartz arenite; and micaceous and feldspathic sandstone and shale interbedded with oolitic ironstone. A Late Cambrian to Middle Ordovician age is constrained by biostratigraphic data, including trilobites (Whittington, 1953), palynomorphs (Andress and others, 1969), graptolites, and conodonts (Pojeta and others, 1976)
O€ch	**Cooks Hammock formation (Ordovician to Cambrian)**—Subarkosic to arkosic sandstone and micaceous sandstone, undifferentiated. A Cambrian to Early Ordovician age is constrained by its stratigraphic position below Upper Cambrian to Middle Ordovician Cherry Lake formation (O€cl) sandstone and above Cambrian sandstones of the Pumpkin Swamp formation
€ps	**Pumpkin Swamp formation (Cambrian)**—Feldspathic and lithic-rich sandstone and conglomerate red beds, undifferentiated. Age is constrained by its stratigraphic position below Cambrian to Lower Ordovician sandstone of the Cooks Hammock formation (O€ch) and above Neoproterozoic to Cambrian volcanic rocks of the North Florida volcanic series (€Znf)

OSCEOLA ARC

€Znf	**North Florida volcanic series (Cambrian to Neoproterozoic)—**Informal name of Heatherington and others (1996). Mafic, intermediate, and felsic extrusive and hypabyssal rocks, undifferentiated. Volcanic rocks, ranging in composition from basalt to rhyolite of the North Florida volcanic series, constitute the extrusive and hypabyssal components of the Osceola arc. Mafic rocks are plagioclase porphyries with dark-green to black microcrystalline matrices. The phenocrysts are acicular to tabular, up to 0.5 mm in maximum dimension. They compose 20 to 80 percent of the rock by volume, and may be randomly oriented or well aligned, the latter interpreted as preserving a magmatic flow fabric. Mafic rocks contain rare sedimentary xenoliths and rare chlorite-filled vugs. Intermediate rocks are green to black welded lapilli tuffs. Tephra are typically 0.5–1 mm in diameter, although some fragments are larger than the size of cuttings fragments (~4 mm); the upper limit of fragment size is unknown. Clasts are angular to rounded pieces of aphanitic or porphyritic volcanic rock with rare quartz, epidote, and sedimentary lithic clasts. Felsic rocks are aphanitic or quartz- and feldspar-porphyries (subhedral to euhedral phenocrysts up to 2 mm across) having very fine grained, tan to buff quartzofeldspathic matrices with rusty Liesegang alteration. All rocks are statically altered at

lower greenschist facies and diagenetic conditions to assemblages including chlorite, actinolite, titanite, epidote, prehnite, andradite, calcite, and magnetite in the mafic and intermediate rocks, as well as hematite, goethite, illite, and kaolinite in the felsic rocks. Planar veins of quartz, epidote, and (or) chlorite ranging in aperture from a few micrometers to >4 mm are common in the mafic and intermediate rocks

€Zo **Osceola intrusive complex (Cambrian to Neoproterozoic)**—Informal name of Boote and others (2018). Coarse-grained, massive intrusive rocks including granodiorite, granite, and granitic pegmatite partially altered to sericite, epidote, illite, and carbonate minerals. Quartz, epidote, and carbonate veins are common. Minor granitic and dioritic rock found within the metamorphic rocks of the St. Lucie Metamorphic Complex (Zsl) may also belong to this unit. A region of low gravity anomaly (fig. 4) is associated with the subcrop extent of this unit

ST. LUCIE METAMORPHIC COMPLEX

Zsl **St. Lucie Metamorphic Complex (Neoproterozoic?)**—Diverse amphibolite-facies metamorphic rocks including biotite schist, dioritic gneiss, and foliated amphibolite (Dallmeyer, 1989b; Thomas and others, 1989). Step-heated $^{40}Ar/^{39}Ar$ analyses of hornblende concentrates from samples from two boreholes (W13082 and W14960) yielded post-metamorphic cooling ages of 510.8±1.1 Ma and 513.1±1.8 Ma, respectively (Dallmeyer, 1989b). The amphibolite facies assemblage is partially replaced by a lower greenschist facies overprint including calcite and chlorite (Bass, 1969); the latter locally completely replaces older ferromagnesian grains (Applin and Applin, 1965)

GASKIN INTRUSIVE COMPLEX

Zg **Gaskin intrusive complex (Neoproterozoic)**—Pink, coarse-grained, massive granite with graphic K-feldspar-quartz intergrowths and strongly altered, inclusion-rich feldspars (W12309); orange, coarse-grained, massive, unaltered graphic granite with euhedral muscovite up to 1 mm in diameter and containing abundant (~1 percent) yellow to green apatite and magnetite, both up to 1 mm in maximum dimension (W12509); and pink to red clinopyroxene- and hornblende-bearing granodiorite with rosette-shaped myrmekitic overgrowths and minor laumontite veins (W12497). Granite from borehole W12509 has U-Pb zircon age of 656±38 Ma (Deasy and others, 2023) and $^{40}Ar/^{39}Ar$ muscovite age of 653.8±3.4 Ma (Deasy and McAleer, 2022). A region of low gravity and high magnetic anomalies (figs. 4 and 5) is associated with the subcrop extent of this unit

References Cited

Andress, N.E., Cramer, F.H., and Goldstein, R.F., 1969, Ordovician chitinozoans from Florida well samples: Gulf Coast Association of Geological Societies Transactions, v. 19, p. 369–375.

Applegate, A.V., Winston, G.O., and Palacas, J.G., 1981, Subdivision and regional stratigraphy of the pre-Punta Gorda rocks (lowermost Cretaceous-Jurassic) in south Florida [abs.]: Gulf Coast Association of Geological Societies Transactions, v. 31, p. 233.

Applin, P.L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent States: U.S. Geological Survey Circular 91, 28 p., accessed February 1, 2022, at https://doi.org/10.3133/cir91.

Applin, P.L., and Applin, E.R., 1965, The Comanche Series and associated rocks in the subsurface in central and south Florida: U.S. Geological Survey Professional Paper 447, 84 p., pls. 1–4 follow index, pls. 5–11 are in pocket. [Also available at https://doi.org/10.3133/pp447.]

Arden, D.D., Jr., 1974, Geology of the Suwannee Basin interpreted from geophysical profiles: Gulf Coast Association of Geological Societies Transactions, v. 24, p. 223–230. [Also available at https://archives.datapages.com/data/gcags/data/024/024001/0223.htm.]

Arthur, J.D., 1988, Petrogenesis of early Mesozoic tholeiite in the Florida basement and an overview of Florida basement geology: Florida Geological Survey Report of Investigation 97, 39 p., accessed September 29, 2021, at https://ufdc.ufl.edu/UF00001284/00001.

Barnett, R.S., 1975, Basement structure of Florida and its tectonic implications: Gulf Coast Association of Geological Societies Transactions, v. 25, p. 122–142, accessed September 29, 2021, at https://archives.datapages.com/data/gcags/data/025/025001/0122.htm.

Bass, M.N., 1969, Petrography and ages of crystalline basement rocks of Florida—Some extrapolations, *in* Bass, M.N., and Cebulski, D.E., 1969, Other papers on Florida and British Honduras: American Association of Petroleum Geologists Memoir, v. 11, p. 283–310.

Beaman, M., Koch, J., Paulson, S., and Krueger, S., 2017, The Florida-Bahamas lineament and Gulf of Mexico opening—To move or not to move?: American Association of Petroleum Geologists Annual Convention and Exhibition, Houston, Texas, April 2–5, 2017, conference presentation, accessed January 7, 2024, at https://www.searchanddiscovery.com/abstracts/html/2017/90291ace/abstracts/2610932.html.

Behrendt, J.C., and Klitgord, K.D., 1979, High resolution aeromagnetic anomaly map of the U.S. Atlantic continental margin: U.S. Geological Survey Geophysical Investigations Map 931, scale 1:1,000,000, accessed February 26, 2024, at https://doi.org/10.3133/gp931.

Boote, S.K., and Knapp, J.H., 2016, Offshore extent of Gondwanan Paleozoic strata in the southeastern United States—The Suwannee suture zone revisited: Gondwana Research, v. 40, p. 199–210, accessed August 21, 2019, at https://doi.org/10.1016/j.gr.2016.08.011.

Boote, S.K., Knapp, J.H., and Mueller, P.A., 2018, Preserved Neoproterozoic continental collision in southeastern North America—The Brunswick suture zone and Osceola continental margin arc: Tectonics, v. 37, no. 1, p. 305–321, accessed September 29, 2021, at https://doi.org/10.1002/2017TC004732.

Bridge, J., and Berdan, J.M., 1951, Preliminary correlation of the Paleozoic rocks from test wells in Florida and adjacent parts of Georgia and Alabama: U.S. Geological Survey Open-File Report 51–13, 8 p., 1 pl., accessed September 29, 2021, at https://doi.org/10.3133/ofr5113.

Campbell, R.B., 1939, Paleozoic under Florida—Geological notes: American Association of Petroleum Geologists Bulletin, v. 23, no. 11, p. 1712–1720, accessed September 29, 2021, at https://archives.datapages.com/data/bulletns/1938-43/data/pg/0023/0011/1700/1712.htm.

Carroll, D., 1963, Petrography of some sandstones and shales of Paleozoic age from borings in Florida: U.S. Geological Survey Professional Paper 454–A, p. A1–A15, accessed September 29, 2021, at https://doi.org/10.3133/pp454A.

Chowns, T.M., and Williams, C.T., 1983, Pre-Cretaceous rocks beneath the Georgia Coastal Plain—Regional implications, chap. L *in* Gohn, G.S., ed., 1983, Studies related to the Charleston, South Carolina, earthquake of 1886—Tectonics and seismicity: U.S. Geological Survey Professional Paper 1313, p. L1–L42, accessed September 29, 2021, at https://doi.org/10.3133/pp1313.

Coleman, N.M., and Stewart, M.T., 1982, Basement structure in northwest peninsular Florida: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 153–156.

Cramer, F.H., 1973, Middle and Upper Silurian chitinozoan succession in Florida subsurface: Journal of Paleontology, v. 47, no. 2, p, 279–288, 2 pls., accessed September 29, 2021, at https://www.jstor.org/stable/1302892.

Dallmeyer, R.D., 1987, ^{40}Ar/^{39}Ar age of detrital muscovite within Lower Ordovician sandstone in the coastal plain basement of Florida—Implications for West African terrane linkages: Geology, v. 15, no. 11, p. 998–1001. [Also available at https://pubs.geoscienceworld.org/geology/issue/15/11.]

Dallmeyer, R.D., 1989a, ^{40}Ar/^{39} Ar ages from subsurface crystalline basement of the Wiggins uplift and southwesternmost Appalachian Piedmont; implications for late Paleozoic terrane accretion during assembly of Pangea: American Journal of Science, v. 289, no. 6, p. 812–828, accessed February 1, 2022, at https://doi.org/10.2475/ajs.289.6.812.

Dallmeyer, R.D., 1989b, A tectonic linkage between the Rokelide orogen (Sierra Leone) and the St. Lucie Metamorphic Complex in the Florida subsurface: Journal of Geology, v. 97, no. 2, p. 183–195, accessed February 1, 2022, at https://www.jstor.org/stable/30065538.

Dallmeyer, R.D., 1989c, Contrasting accreted terranes in the southern Appalachian orogen, basement beneath the Atlantic and Gulf Coastal Plains, and West African orogens: Precambrian Research, v. 42, nos. 3–4, p. 387–409, accessed September 29, 2021, at https://doi.org/10.1016/0301-9268(89)90021-1.

Dallmeyer, R.D., Caen-Vachette, M., and Villenueve, M., 1987, Emplacement age of post-tectonic granites in southern Guinea (West Africa) and the peninsular Florida subsurface—Implications for origins of southern Appalachian exotic terranes: Geological Society of America Bulletin, v. 99, no. 1, p. 87–93. [Also available at https://doi.org/10.1130/0016-7606(1987)99<87:EAOPGI>2.0.CO;2.]

Daniels, D.L., and Leo, G.W., 1985, Geologic interpretation of basement rocks of the Atlantic Coastal Plain: U.S. Geological Survey Open-File Report 85–655, 45 p., 4 map sheets, scale 1:1,000,000, accessed May 31, 2023, at https://doi.org/10.3133/ofr85655.

Dater, D., Metzger, D., and Hittleman, A., comps., 1999, Land and marine gravity CD-ROMs—1999 edition: Boulder, Colo., U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center publication, 2 CD–ROMs.

Deasy, R.[T.], Holm-Denoma, C., McAleer, R.J., Pianowski, L., and Horton, J.W., Jr., 2023, New geo- and thermochronological constraints on the architecture and evolution of the Suwannee terrane, Florida, USA [abs.]: Geological Society of America Abstracts with Programs, v. 55, no. 2, accessed March 19, 2023, at https://doi.org/10.1130/abs/2023SE-385536.

Deasy, R.T., Horton, J.W., Jr., Glock, S.N., and Lupo, M.E., 2024a, Geochemical data from selected pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains in Florida and Alabama: U.S. Geological Survey data release, accessed May 30, 2024, at https://doi.org/10.5066/P13NBKKC.

Deasy, R.T., Horton, J.W., Jr., Glock, S.N., and Lupo, M.E., 2024b, Mineral abundances of selected pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains in Florida and Alabama from whole-rock powder X-ray diffraction analysis and the Rietveld method: U.S. Geological Survey data release, accessed November 11, 2024, at https://doi.org/10.5066/P133DRW5.

Deasy, R.T., Lupo, M.E., McAleer, R.J., and Horton, J.W., Jr., 2024c, Photographs and photomicrographs of selected pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains in Florida (ver. 1.1, June 2026): U.S. Geological Survey data release, accessed June 3, 2026, at https://doi.org/10.5066/P13XYCUC.

Deasy, R.T., Horton, J.W., Jr., Glock, S.N., Lupo, M.E., Crider, E.A., Jr., and Daniels, D.L., 2026a, Database for the geologic map of pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains in Florida: U.S. Geological Survey data release, https://doi.org/10.5066/P13WJTCW.

Deasy, R.T., Lupo, M.E., McAleer, R.J., and Horton, J.W., Jr., 2026b, Petrography and mineralogy of selected pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains in Florida: U.S. Geological Survey Data Report 1209, 150 p., https://doi.org/10.3133/dr1209.

Deasy, R.T., and McAleer, R.J., 2022, Basement infrastructure of northwest Florida revealed by $^{40}Ar/^{39}Ar$ age spectra of K-feldspar and muscovite [abs.]: Geological Society of America Abstracts with Programs, v. 54, no. 4, accessed April 7, 2022, at https://doi.org/10.1130/abs/2022NC-373769.

Duncan, J.G., 1998, Geological history of an accreted terrane—Stratigraphy of the north Florida basin, Suwannee terrane: Tallahassee, Fla., Florida State University, Ph.D. dissertation, 259 p., 4 pls., accessed October 17, 2024, at https://www.proquest.com/openview/f22d1ca07bca737a96c494aed7d274f9/1?pq-origsite=gscholar&cbl=18750&diss=y.

Ehrlich, R.N., and Pindell, J., 2021, Crustal origin of the West Florida terrane, and detrital zircon provenance and development of accommodation during initial rifting of the southeastern Gulf of Mexico and western Bahamas: Geological Society, London, Special Publications, v. 504, no. 1, p. 77–118, accessed February 24, 2022, at https://doi.org/10.1144/sp504-2020-14.

Florida Geological Survey, 2023, GEODES [GEOlogic Data Enterprise System]—Wells in FGS inventory: Florida Department of Environmental Protection website, accessed April 13, 2023, at https://geodes.kyrasolutions.com.

Frederick, B.C., Blum, M.D., Snedden, J.W., and Fillon, R.H., 2020, Early Mesozoic synrift Eagle Mills Formation and coeval siliciclastic sources, sinks, and sediment routing, northern Gulf of Mexico basin: Geological Society of America Bulletin, v. 132, nos. 11–12, p. 2631–2650, accessed September 29, 2021, at https://doi.org/10.1130/B35493.1.

Goldstein, R.F., Cramer, F.H., and Andress, N.E., 1969, Silurian chitinozoans from Florida well samples: Gulf Coast Association of Geological Societies Transactions, v. 19, p. 377–384, 2 pls., accessed September 29, 2021, at http://archives.datapages.com/data/gcags/data/019/019001/0377.htm?q=%2BtextStrip%3Agoldstein.

Gorton, M.P., and Schandl, E.S., 2000, From continents to island arcs—A geochemical index of tectonic setting for arc-related and within-plate felsic to intermediate volcanic rocks: The Canadian Mineralogist, v. 38, no. 5, p. 1065–1073. [Also available at https://doi.org/10.2113/gscanmin.38.5.1065.]

Grasty, R.L., and Wilson, J.T., 1967, Ages of Florida volcanics and of opening of the Atlantic Ocean [abs.]: American Geophysical Union Transactions, v. 48, no. 1, p. 212–213, accessed February 1, 2022, at https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/TR048i001p00003.

Guthrie, G.M., and Raymond, D.E., 1992, Pre-Middle Jurassic rocks beneath the Alabama Gulf Coastal Plain: Geological Survey of Alabama Bulletin, v. 150, 155 p.

Heatherington, A.L., and Mueller, P.A., 1991, Geochemical evidence for Triassic rifting in southwestern Florida: Tectonophysics, v. 188, nos. 3–4, p. 291–302. [Also available at https://www.sciencedirect.com/journal/tectonophysics/vol/188/issue/3.]

Heatherington, A.L., and Mueller, P.A., 1994, Late Proterozoic magmatism in the Suwannee terrane and possible correlations with Avalonian rocks [abs.]: Geological Society of America Abstracts with Programs, v. 26, no. 3, p. 22–23.

Heatherington, A.L., and Mueller, P.A., 1999, Lithospheric sources of North Florida, USA, tholeiites and implications for the origin of the Suwannee terrane: Lithos, v. 46, no. 2, p. 215–233. [Also available at https://doi.org/10.1016/S0024-4937(98)00063-2.]

Heatherington, A.L., and Mueller, P.A., 2003, Mesozoic igneous activity in the Suwannee terrane, southeastern USA—Petrogenesis and Gondwanan affinities: Gondwana Research, v. 6, no. 2, p. 296–311, accessed September 29, 2021, at https://doi.org/10.1016/S1342-937X(05)70979-5.

Heatherington, A.L., Mueller, P.A., and Nutman, A.P., 1996, Neoproterozoic magmatism in the Suwannee terrane—Implications for terrane correlation, *in* Nance, R.D., and Thompson, M.D., eds., Avalonian and related peri-Gondwanan terranes of the circum-North Atlantic: Geological Society of America Special Paper 304, p. 257–268, accessed September 29, 2021, at https://doi.org/10.1130/SPE304.

Heatherington, A.L., Mueller, P.A., and Wooden, J.L., 2010, Alleghanian plutonism in the Suwannee terrane, USA—Implications for late Paleozoic tectonic models, *in* Tollo, R.P., Bartholomew, M.J., Hibbard, J.P., and Karabinos, P.M., From Rodinia to Pangea—The lithotectonic record of the Appalachian region: Geological Society of America Memoir, v. 206, p. 607–620, accessed September 29, 2021, at https://doi.org/10.1130/2010.1206(24).

Heffner, D.M., 2013, Tectonics of the South Georgia rift: Columbia, S.C., University of South Carolina, Ph.D. dissertation, 165 p., accessed September 29, 2021, at https://scholarcommons.sc.edu/etd/1330/.

Higgins, M.W., and Zietz, I., 1983, Geologic interpretation of geophysical maps of the pre-Cretaceous “basement” beneath the Coastal Plain of the southeastern United States, *in* Hatcher, R.D., Jr., Williams, H., and Zietz, I., eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 125–130. [Also available at https://doi.org/10.1130/MEM158-p125.

Hill, P.L., Kucks, R.P., and Ravat, D., 2009, Aeromagnetic and aeroradiometric data for the conterminous United States and Alaska from the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy: U.S. Geological Survey Open-File Report 2009–1129, accessed February 26, 2024, at https://doi.org/10.3133/ofr20091129.

Horton, J.W., Jr., Drake, A.A., Jr., and Rankin, D.W., 1989, Tectonostratigraphic terranes and their Paleozoic boundaries in the central and southern Appalachians, *in* Dallmeyer, R.D., ed., Terranes in the circum-Atlantic Paleozoic orogens: Geological Society of America Special Paper 230, p. 213–245, accessed January 31, 2024, at https://doi.org/10.1130/SPE230-p213.

Horton, J.W., Jr., Drake, A.A., Jr., Rankin, D.W., and Dallmeyer, R.D., 1991, Preliminary tectonostratigraphic terrane map of the central and southern Appalachians: U.S. Geological Survey Miscellaneous Investigations Series Map I–2163, scale 1:2,000,000, 15-p. pamphlet, accessed January 31, 2024, at https://doi.org/10.3133/i2163.

Horton, J.W., Jr., Glock, S.N., Daniels, D.L., and Deasy, R.T., 2023, Borehole data for pre-Middle Jurassic basement rocks beneath the Atlantic and Gulf Coastal Plains, Florida and Alabama (ver. 1.1, June 2026): U.S. Geological Survey data release, accessed June 3, 2026, at https://doi.org/10.5066/P9VBO427.

Horton, J.W., Jr., Zietz, I., and Neathery, T.L., 1984, Truncation of the Appalachian Piedmont beneath the Coastal Plain of Alabama—Evidence from new magnetic data: Geology, v. 12, no. 1, p. 51–55, accessed May 31, 2023, at https://doi.org/10.1130/0091-7613(1984)12<51:TOTAPB>2.0.CO;2.

Howell, B.F., and Richards, H.G., 1949, New Paleozoic linguloid brachiopod from Florida: Wagner Free Institute of Science Bulletin, v. 24, no. 4, p. 35–36, pl. 1.

Hutley, J.K., 1985, Triassic/Jurassic faulting patterns of Conecuh Ridge, southwest Alabama [abs.]: American Association of Petroleum Geologists Bulletin, v. 69, no. 2, p. 268–269, accessed February 23, 2024, at https://www.osti.gov/biblio/5785704.

King, P.B., 1961, The subsurface Ouachita structural belt east of the Ouachita Mountains, *in* Flawn, P.T., Goldstein, A., Jr., King, P.B., and Weaver, C.E., eds., The Ouachita System: Austin, Tex., University of Texas, Bureau of Economic Geology Publication 6120, p. 83–98.

Kjellesvig-Waering, E.N., 1955, A new phyllocarid and eurypterid from the Silurian of Florida: Journal of Paleontology, v. 29, no. 2, p. 295–297, accessed October 17, 2024, at https://www.jstor.org/stable/pdf/1300471.pdf?casa_token=Y0hhTxioNw0AAAAA:K-tKFtHxSbA6bu19TT8BnmIu-3v4JUwtolCxTTzwWKzSnuQYhlt8qYefGjt_PQaydm8vbTfiO673rNr2GwkwJMwjO4CQXW1NoFyz1jvF41jtPTG5iOEw.

Klitgord, K.D., Popenoe, P., and Schouten, H., 1984, Florida—A Jurassic transform plate boundary: Journal of Geophysical Research – Solid Earth, v. 89, no. B9, p. 7753–7772. [Also available at https://doi.org/10.1029/JB089iB09p07753.]

Le Bas, M.J., LeMaitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, no. 3, p. 745–750. [Also available at https://doi.org/10.1093/petrology/27.3.745.]

Lloyd, J.M., 1985, Annotated bibliography of Florida basement geology and related regional and tectonic studies, including an appendix of Florida deep well data: Florida Geological Survey Information Circular 98, 72 p., accessed September 29, 2021, at https://ufdc.ufl.edu/UF00001159/00001.

Marzoli, A., Callegaro, S., Dal Corso, J., Davies, J.H.F.L., Chiaradia, M., Youbi, N., Bertrand, H., Reisberg, L., Merle, R., and Jourdan, F., 2017, The central Atlantic magmatic province (CAMP)—A review, chap. 4 *in* Tanner, L.H., ed., The Late Triassic world—Earth in a time of transition: Springer International Publishing AG, Topics in Geobiology series, v. 46, p. 91–125, accessed September 10, 2022, at https://link.springer.com/chapter/10.1007/978-3-319-68009-5_4.

Milton, C., 1972, Igneous and metamorphic basement rocks of Florida: Florida Geological Survey Bulletin, v. 55, 125 p., accessed September 29, 2021, at https://ufdc.ufl.edu/UF00000245/00001/5j.

Milton, C., and Grasty, R., 1969, “Basement” rocks of Florida and Georgia: American Association of Petroleum Geologists Bulletin, v. 53, no. 12, p. 2483–2493, accessed September 29, 2021, at http://archives.datapages.com/data/bulletns/1968-70/data/pg/0053/0012/2450/2483.htm?q=%2BtextStrip%3Amilton+textStrip%3Agrasty.

Montgomery, S.L., 2000, Wiggins arch, southern Mississippi—New exploratory data from 3-D seismic: American Association of Petroleum Geologists Bulletin, v. 84, no. 3, p. 299–313, accessed September 29, 2021, at https://doi.org/10.1306/C9EBCDD3-1735-11D7-8645000102C1865D.

Muehlberger, W.R., Hedge, C.E., Denison, R.E., and Marvin, R.F., 1966, Geochronology of the midcontinent region, United States—3. Southern area: Journal of Geophysical Research, v. 71, no. 22, p. 5409–5426.

Mueller, P.A., Heatherington, A.L., Wooden, J.L., Shuster, R.D., Nutman, A.P., and Williams, I.S., 1994, Precambrian zircons from the Florida basement—A Gondwanan connection: Geology, v. 22, no. 2, p. 119–122, accessed September 1, 2019, at https://doi.org/10.1130/0091-7613(1994)022<0119:PZFTFB>2.3.CO;2.

Mueller, P.A., Heatherington, A.L., Foster, D.A., Thomas, W.A., and Wooden, J.L., 2014, The Suwannee suture—Significance for Gondwana-Laurentia terrane transfer and formation of Pangaea: Gondwana Research, v. 26, no. 1, p. 365–373, accessed August 17, 2019, at https://doi.org/10.1016/j.gr.2013.06.018.

Mueller, P.A., and Porch, J.W., 1983, Tectonic implications of Paleozoic and Mesozoic igneous rocks in the subsurface of peninsular Florida: Gulf Coast Association of Geological Societies Transactions, v. 33, p. 169–173, accessed September 29, 2021, at https://archives.datapages.com/data/gcags/data/033/033001/0169.htm?q=%2BtextStrip%3Amueller+textStrip%3Aporch.

Nemčok, M., Rybár, S., Odegard, M., Dickson, W., Pelech, O., Ledvényiová, L., Matejová, M., Molčan, M., Hermeston, S., Jones, D., Cuervo, E., Cheng, R., and Forero, G., 2016, Development history of the southern terminus of the central Atlantic; Guyana–Suriname case study: Geological Society of London Special Publications, v. 431, no. 1, p. 145–178, accessed April 10, 2020, at https://doi.org/10.1144/SP431.10.

Opdyke, N.D., Jones, D.S., MacFadden, B.J., Smith, D.L., Mueller, P.A., and Shuster, R.D., 1987, Florida as an exotic terrane—Paleomagnetic and geochronologic investigation of lower Paleozoic rocks from the subsurface of Florida: Geology, v. 15, no. 10, p. 900–903, accessed April 10, 2020, at https://doi.org/10.1130/0091-7613(1987)15<900:FAAETP>2.0.CO;2.

Pojeta, J., Jr., Kříž, J., and Berdan, J.M., 1976, Silurian-Devonian pelecypods and Paleozoic stratigraphy of subsurface rocks in Florida and Georgia and related Silurian pelecypods from Bolivia and Turkey: U.S. Geological Survey Professional Paper 879, 32 p., 5 pls., accessed September 29, 2021, at https://doi.org/10.3133/pp879.

Reagor, B.G., Stover, C.W., and Algermissen, S.T., 1987, Seismicity map of the state of Florida: U.S. Geological Survey Miscellaneous Field Studies Map 1056, scale 1:1,000,000, accessed February 26, 2024, at https://doi.org/10.3133/mf1056.

Richards, H.G., 1948, Studies on the subsurface geology and paleontology of the Atlantic Coastal Plain: Proceedings of the Academy of Natural Sciences of Philadelphia, v. 100, p. 39–76, accessed October 17, 2024, at https://www.jstor.org/stable/pdf/4064415.pdf?casa_token=enTuBhEnY1EAAAAA:7vTY_NqS3lSWTYIbd3sJ4ynGMG2YdpLEXdSt2zTqR8TeQPaqmBMkyNY0nmL5EDJsjiUokU2kgrXXGXWNRM65YAnSFuag3C1WExAmiR__ixHrjxPTLDaC.

Scholle, P.A., ed., 1979, Geological studies of the COST GE-1 well, United States south Atlantic Outer Continental Shelf area: U.S. Geological Survey Circular 800, 114 p., accessed April 10, 2020, at https://pubs.usgs.gov/circ/1979/0800/report.pdf.

Shand, S.J., 1943, Eruptive rocks, 2d. ed.: New York, John Wiley, 444 p.

Smith, D.L., 1983, Basement model for the panhandle of Florida: Gulf Coast Association of Geological Societies Transactions, v. 33, p. 203–208, accessed April 10, 2020, at https://archives.datapages.com/data/gcags/data/033/033001/0203.htm?q=%2BtextStrip%3Asmith.

Smith, D.L., 1993, Role of continental closure in the distribution of Florida basement features, *in* Pindell, J.L., and Perkins, R.F., eds., Mesozoic and Early Cenozoic development of the Gulf of Mexico and Caribbean region—A context for hydrocarbon exploration: SEPM, Society for Sedimentary Geology, Gulf Coast Section, p. 1–8, accessed April 10, 2020, at https://doi.org/10.5724/gcs.92.13.0001.

Streckeisen, A.L., 1973, Plutonic rocks—Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, no. 10, p. 26–30.

Taylor, P.T., Zietz, I., and Dennis, L.S., 1968, Geologic implications of aeromagnetic data for the eastern continental margin of the United States: Geophysics, v. 33, no. 5, p. 755–780, accessed February 26, 2024, at https://doi.org/10.1190/1.1439970.

Thébault, E., Finlay, C.C., Beggan, C.D., Alken, P., Aubert, J., Barrois, O., Bertrand, F., Bondar, T., Boness, A., Brocco, L., Canet, E., Chambodut, A., Chulliat, A., Coïsson, P., Civet, F., Du, A., Fournier, A., Fratter, I., Gillet, N., Hamilton, B., Hamoudi, M., Hulot, G., Jager, T., Korte, M., Kuang, W., Lalanne, X., Langlais, B., Léger, J-M., Lesur, V., Lowes, F.J., Macmillan, S., Mandea, M., Manoj, C., Maus, S., Olsen, N., Petrov, V., Ridley, V., Rother, M., Sabaka, T.J., Saturnino, D., Schachtschneider, R., Sirol, O., Tangborn, A., Thomson, A., Tøffner-Clausen, L., Vigneron, P., Wardinski, I., and Zvereva, T., 2015, International Geomagnetic Reference Field—The 12th generation: Earth, Planets and Space, v. 67, no. 79, 19 p. [Also available at https://doi.org/10.1186/s40623-015-0228-9.]

Thomas, W.A., 2010, Interactions between the southern Appalachian-Ouachita orogenic belt and basement faults in the orogenic footwall and foreland, *in* Tollo, R.P., Bartholomew, M.J., Hibbard, J.P., and Karabinos, P.M., eds., From Rodinia to Pangea—The lithotectonic record of the Appalachian region: Geological Society of America Memoir 206, p. 897–916, accessed January 31, 2024, at https://doi.org/10.1130/2010.1206(34).

Thomas, W.A., Chowns, T.M., Daniels, D.L., Neathery, T.L., Glover, L., III, and Gleason, R.J., 1989, Pre-Mesozoic paleogeologic map of Appalachian Ouachita orogen beneath Atlantic and Gulf Coastal Plains, *in* Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colo., Geological Society of America, The Geology of North America, v. F-2, pl. 6, scale 1:2,500,000.

U.S. Geological Survey, 1978a, Aeromagnetic [map] of north-central Florida: U.S. Geological Survey Open-File Report 78–761, 1 sheet, scale 1:250,000, accessed February 26, 2024, at https://doi.org/10.3133/ofr78761.

U.S. Geological Survey, 1978b, Aeromagnetic map of northern Florida: U.S. Geological Survey Open-File Report 78–891, 2 sheets, scale 1:250,000, accessed February 26, 2024, at https://doi.org/10.3133/ofr78891.

U.S. Geological Survey, 1978c, Aeromagnetic map of part of the Apalachicola 1° x 2° quadrangle, Florida: U.S. Geological Survey Open-File Report 78–714, 1 sheet, scale 1:250,000, accessed February 26, 2024, at https://doi.org/10.3133/ofr78714.

U.S. Geological Survey, 1978d, Aeromagnetic map of part of the Pensacola 1° x 2° quadrangle, Florida: U.S. Geological Survey Open-File Report 78–716, 1 sheet, scale 1:250,000, accessed February 26, 2024, at https://doi.org/10.3133/ofr78716.

U.S. Geological Survey, 2024, Earthquake lists, maps, and statistics: U.S. Geological Survey Earthquake Hazards Program web page, accessed February 23, 2024, at https://www.usgs.gov/programs/earthquake-hazards/lists-maps-and-statistics.

U.S. Naval Oceanographic Office, 1970, U.S. Naval Oceanographic Office Geomagnetic Surveys: U.S. Naval Oceanographic Office Informal Report 70–18, 90 p., accessed February 26, 2024, at https://apps.dtic.mil/sti/tr/pdf/AD0741064.pdf.

Wait, R.L., and Davis, M.E., 1986, Configuration and hydrology of the pre-Cretaceous rocks underlying the southeastern Coastal Plain aquifer system: U.S. Geological Survey Water-Resources Investigations Report 86–4010, 1 sheet, scale 1:2,000,000. [Also available at https://doi.org/10.3133/wri864010.]

Whittington, H.B., 1953, A new Ordovician trilobite from Florida: Breviora, Museum of Comparative Zoology, no. 17, p. 1–6.

Williams, H., and Hatcher, R.D., Jr., 1983, Appalachian suspect terranes, *in* Hatcher, R.D., Jr., Williams, H., and Zietz, I., eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 33–53. [Also available at https://doi.org/10.1130/MEM158-p33.]

Williams, L.J., Raines, J.E., and Lanning, A.E., 2016, Geophysical log database for the Floridan aquifer system and southeastern Coastal Plain aquifer system in Florida and parts of Georgia, Alabama, and South Carolina (ver. 1.1, December 2016): U.S. Geological Survey Data Series 760, 12 p., accessed April 11, 2020, at https://pubs.usgs.gov/ds/760/.

Wilson, J.T., 1966, Did the Atlantic close and then reopen?: Nature, v. 211, p. 676–681.

Winchester, J.A., and Floyd, P.A., 1976, Geochemical magma type discrimination—Application to altered and metamorphosed basic igneous rocks: Earth and Planetary Science Letters, v. 28, no. 3, p. 459–469.

Winston, G.O., 1992, “African” Paleozoic sedimentary rocks of the west Suwannee basin: Coral Gables, Fla., Miami Geological Society, 24 p.

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